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FORCES OF ACCELERATION

In recent years engineers have had to pay increasing attention to the effects of high speeds and the results of the acceleration forces that produce them, or arise from them. If this is so with engineers in general it is especially the case with those concerned with aeronautics. Although it may be true that it was due to physicists and astronomers that the careful study of acceleration and its many effects first began, it has in the present century become a vital study for engineers and biologists. For the technical study of acceleration the first problem was how best to measure it. Herein credit must be given to F. W. Lanchester, who, in the early days of his work in the development of the automobile, adapted a form of the familiar spirit level to this end. But since with such a device the "pointer" was necessarily just a spherical bubble, it was soon found that some more precise tool was needed. This was supplied by the use of a needle pointer attached to a horizontal copper disc which was damped in its angular motion by a small permanent magnet, and had a hole bored near its circumference to throw its centre of gravity slightly out of its centre of form. This instrument, when placed on any moving vehicle, gave an easy means of reading off the acceleration at any moment. As it happened, one of its chief uses lay in the convenient fact that when the vehicle was coasting with its motive power cut off, the reading gave at once the tractive resistance (or the braking resistance, if desired) in pounds per ton; if the road or track was not level, the acceleration would be increased or decreased by an amount which, as it conveniently happened, exactly balanced the effect of any such tilting of the instrument, so that the correct reading of tractive resistance was still given; experience showed, indeed, that the most convenient means of experiment was to choose a slight downward slope, since there was then more time in which to take precise readings.

When in the wide field of transport, aviation became an important feature the measurement of acceleration was of even greater importance; for the centrifugal forces during aerobatic manœuvre induced the severest form of loading that aircraft had to sustain. Moreover, such forces fluctuate rapidly and make it necessary to take a very conservative attitude in guarding against the risk of failure by fatigue. These high accelerations affect not only the structure of the craft, but the body of its pilot or other occupants. Indeed, such a manœuvre as "looping" gave rise to higher accelerations than those previously encountered; high readings occurred also during tight turns, spins and "outside" loops. The most the human body can safely withstand was soon found to be 10*g* or thereabouts—and less than this could lead to what became known as a "black out" or "red out," in the two modes of looping. As regards the inside loop the blacking out effect was commonly attributed to the drainage of blood from the head, but those who should know tell us that this does not really happen and that what occurs is that the pressure-difference by which the heart maintains normal circulation ceases to be sufficient for the purpose. All this assumes that the pilot is seated in the normal way, but when he adopts the prone position now being tried in certain novel forms of airframe, any high acceleration should have far less troublesome physiological effects. It is reported that in such cases the acceleration at right angles to the fore-and-aft line of the aircraft may rise to 12*g*, or even 15*g*, without serious bodily discomfort. This increasing interest in acceleration forces has lately been manifested by the building at Farnborough of a "centrifuge," costing (with its 2200 h.p. motor) some £350,000. This machine we described in our issue of May 27th. In it the acceleration can be raised to as high a level as 30*g* to provide for the testing of complex apparatus, placed inside one of the test cabins pivoted at the ends of the whirling arm of the mechanism. It is easy to believe that the use of this device will be welcomed also by those concerned with the study of certain biological factors, including the effect on the minute electrical currents which operate during the functioning of heart and brain.

Aircraft designers certainly need to be kept aware of the effect on pilots and passengers of accelerations of every sort likely to be encountered during normal use of the machines they build; here they depend on the help of the biologist.

If mankind should ever have the opportunity of visiting another planet, experience would no doubt be gained *en route* of what human life is like when gravitational effects are almost entirely wiped out ; hence it is not without interest that by the use of a smaller form of centrifuge erected in a physiological laboratory at Cambridge, an investigation has been made into the effect on living beings (laboratory rats) of spending their lives entirely under 3*g* conditions. Into the immediate purpose of these particular tests we need not enter, but it is of general interest that the animals, on being suddenly released to live at 1*g* instead of 3*g*, did literally " jump for joy "

A LOCOMOTIVE EXPERIMENT

At the time when the designs for some large freight locomotives were being prepared, it was decided to equip some of those engines with a boiler of the Franco Crosti type for experimental purposes. The original locomotives, constitute one of the B.R. standard types known as class " 9 " and were built in accordance with the requirements of Mr. R. A. Riddles, at that time Executive Member for Mechanical and Electrical Engineering, who also initiated this interesting experiment, for which the design work was carried out at Brighton. From the description of the first of these modified engines, recently completed, which we published in our issue of June 17th, it will be realised that the boiler is of the normal locomotive type, the innovation consisting only of the addition of an economiser arranged in series with the boiler proper and through which the gases liberated by the boiler pass on their way to the chimney. Basically, the idea is therefore by no means new ; further, it has been applied before in substantially the same manner to a locomotive some years ago by F. H. Trevithick when chief mechanical engineer of the Egyptian State Railways, whose extensive experiments with feed water heaters are well known. It is of particular interest to recall that the first of these experiments consisted of a long cylindrical chamber, carried horizontally over the top of the boiler and terminating in a chimney at the back of the footplate. The exhaust steam passed through a pipe in the cylindrical chamber and the smokebox gases through a series of small tubes fitted between tube plates, one end being open to the smokebox and the other to a chamber at the chimney end in which was fitted the exhaust steam nozzle. In principle this heater was, therefore, exactly as the heater now fitted to these new engines.

While this novel type of economiser met with some success, it was finally abandoned owing to the emission of water and damp vapour over the train, due, of course, to the chimney being at the rear end of the engine. The economiser as applied to the new British locomotive is arranged under the boiler and so between the engine frames and is therefore applicable only to locomotives having outside cylinders. Further, as in the case of the Trevithick design, emission of the smoke and exhaust steam takes place at the rear end of the engine. A noticeable and important feature of this particular application is seen in the boiler itself, which differs materially from the standard design. The total heating surfaces, including the superheater, are now only 1843 square feet, comparing with 2550 for the standard boiler. This is a reduction of 28 per cent. The grate area is 40·2 square feet for each of these boilers, from which it follows that the heating surfaces allowed for each square foot of grate area are respectively 46 and 63·6 square feet.

Allowing for the possibility of having to reduce the size of the boiler proper to compensate for the extra weight of the large supplementary boiler or economiser, it is not clear why the basic proportions of the boilers should be so widely different. If it is assumed that each square foot of grate produces the same amount of heat in each case, then the boiler with the smaller heat-absorbing surfaces might reasonably be expected to be less efficient than a boiler with larger heating surface in relation to the size of the grate. Further, any loss of efficiency would be reflected in the higher temperatures of the gases discharged by the boiler tubes and flues. There is little doubt that placing an economiser between the boiler and the chimney will enable heat to be reclaimed that would otherwise be lost. On the other hand, we would feel more satisfied with this application had it been applied to a standard boiler than to one which would appear to have been designed to suit the economiser instead of the latter being constructed to suit the boiler. In the meantime the working results shown by this experiment are awaited and will no doubt be of interest.

CENTENARIANS

Shakespeare's seven ages of man apply not to men alone, but to the organisations that men create. A journal such as this, a learned society, a manufacturing or consulting firm all suffer the pangs of birth, stumble through the errors and embarrassments of childhood, reach securer ground in maturity, expand and develop, and then often, as history shows, suffer a decline, languish and finally perish. But by contrast to man's limited expectation of a life of threescore years and ten, that of organisations can be far longer. In the engineering and allied fields to-day there are several firms in this country which can contemplate two or even three hundred years of continuous activity ; and there are many which have lived without a break for over 100 years. If—as seems to us rather probable !—this journal continues publication until January 4th next year, it will have the honour of being numbered amongst the latter.

To mark the event we shall issue a special Centenary Number. In that number we would like to include a list of British manufacturing or consulting firms, institutions and societies, and journals, operating in the engineering, iron and steel, shipbuilding, and other fields with which this journal is associated, that will have celebrated their centenaries by January 4, 1956. We ask, therefore, each such firm, institution and journal to inform us not later than September 5th about the date of its foundation, its title at that time and present title. The information should be sent to The Editor, THE ENGINEER, 28, Essex Street, London, W.C.2. It is appreciated, of course, that it is not always easy to determine whether a centenary can justly be claimed. For bankruptcy and winding up is not the final fate of all organisations that cease to have a separate existence. Some firms cease to be known under their former titles because they are taken over by or amalgamate with other firms. But whether those firms can be said to go out of existence depends less upon the exact financial and other arrangements made at the time than upon the degree to which the individuality of the firms concerned survives the change. Where there has been a true amalgamation it seems to us fair to hold that the history of the joint concern dates back to the foundation of its oldest root. But when a young firm has taken over and suppressed the individuality of an older concern we cannot help but regard the older concern as dead. Sometimes, over the decades, firms have grouped themselves together into single financial units, under holding companies, or under some form of common direction. But, providing they continue to manufacture, to trade, and to carry out their major functions under their own titles and thus retain an essential individuality, it can surely be held that each in turn is entitled in due course to celebrate its own centenary. Since, then, there may sometimes be doubt whether a particular firm or organisation may fairly claim to have had a continuous life of over 100 years, we might conclude this article with the curt, but customary, announcement that the decision of the Editor will be final. We shall do no such thing ! It will be our object in publishing the list to do honour to those firms and organisations that have given longer continuous service to the engineering industries than have we ourselves. In such a matter, it is not for upstart youth to attempt invidious distinctions! Whether or not a firm or organisation has had a continuous existence for over 100 years is something that it can best itself decide.

A Seven Day Journal

"Model Engineer" Exhibition

THE thirtieth "Model Engineer" Exhibition opens on Wednesday next, August 17th at the New Horticultural Hall, Westminster, and this year for the first time it will be held jointly with the Exhibition of Inventions organised by the Institute of Patentees. Preliminary information received from the organisers indicates that as in previous years the models will cover practically all aspects of engineering as well as many other subjects, and a number of interesting displays have been arranged by manufacturers of model making equipment. Models are being submitted for the various national competitions by people from all walks of life and of ages ranging from a schoolboy of 13 to an octogenarian. As in former years railways, ships and aircraft will be seen to be the most popular subjects of the modeller although much ingenuity and skill are being increasingly devoted to models covering a much wider field as the popularity of this all-absorbing hobby steadily grows. We understand that an outstanding model in the marine section will be one of the German commerce raider "Atlantis," which at a touch reveals all the devices used to disguise the vessel and to turn it quickly from a merchantman to a man of war. Two recently introduced trophies will be presented; one, the Duke of Edinburgh Trophy for models which have been seen before but sufficiently long ago to be new to the modern generation, and the other the Students Cup for technical classes of schools, apprentices groups, or individual students or trainees.

New Reactor at Harwell

THE United Kingdom Atomic Energy Authority has announced that a full scale, very low-power model of the Dounreay fast reactor has been built at Harwell and should be in operation before the end of this year. It has been named "Zeus" (Zero Energy Uranium System) and will provide data relating to the design and operation of the Dounreay experimental plant which is designed to produce electricity. "Zeus" is a fast reactor like "Zephyr" (the Zero Energy Fast Reactor) and the reacting core contains only the fuel, its canning material, and the coolant. There is no moderating material like heavy water or graphite to slow down the neutrons. However, being a full scale model of an actual power reactor, it is much larger than "Zephyr." The fuel is uranium highly enriched in Uranium-235 (from the diffusion plant at Capenhurst), instead of the plutonium fuel used in "Zephyr." The fuel is in the form of long tubes which are mounted vertically to form a hexagonal shaped core. The core is surrounded by an envelope or blanket of natural uranium, the purpose of which is to absorb the neutrons from the core and so produce plutonium. The Dounreay reactor and "Zeus" are both breeder reactors, though it is not expected that the breeding margin will be as high as it was in "Zephyr," where the amount of fresh plutonium produced in the reactor was found to be about double the amount consumed in the core. The operating power level of the new reactor will be only about one millionth of that of the proposed Dounreay reactor. This will be sufficient for the experimental studies, which are to be carried out on it, without leading to many of the engineering difficulties associated with operation at high power. Staff from the industrial group of the Atomic Energy Authority who will be responsible for running the high-power reactor at Dounreay, will take part in the operation of "Zeus." The Authority points out that the original purpose of the development of fast reactors was the efficient utilisation of the uranium, made possible by breeding. Because of the complex technical problems which they pose, fast reactors will not play a prominent part in the early stages of the utilisation of atomic energy, but when they do come into widespread use they will make it possible for a substantial supply of fissile material to be obtained economically from a relatively modest supply of uranium.

National Research Development Corporation

THE Board of Trade has announced this week that Sir Percy Mills, Bt., has asked to be allowed to relinquish the chairmanship of the National Research Development Corporation. It may be recalled that the Corporation was set up in June 1949 in accordance with the provisions of the Development of Inventions Act, 1948. Its principal function is to secure, where the public interest so requires, the development and exploitation of inventions resulting from publicly financed research. The Corporation is also empowered to develop and exploit inventions from other sources such as private firms and individuals, if they appear to be worth while and are not otherwise being brought into use. Sir Percy Mills has served as chairman of the Corporation since its establishment in 1949. During the intervening period, the Board of Trade says, the Corporation has aquired a large portfolio of patents and has introduced several hundred inventions into British industry. Sir Percy is resigning the chairmanship—which is a part-time appointment—for business reasons. He is chairman of W. and T. Avery, Ltd., deputy-chairman of Lancashire Dynamo Holdings, Ltd., and a director of several other companies. Sir Alan Saunders, who has been a member of the Corporation since June 1954, has been appointed to succeed Sir Percy Mills as chairman. Sir Alan is the chairman of the British Sugar Corporation, Ltd.

Radio-Astronomy at Cambridge

THE University of Cambridge, with the help of a benefaction of £100,000 from the Mullard Company, is to set up a new observatory, to be known as the Mullard Radio-Astronomy Observatory. The radio-telescopes developed since the war have detected radio waves from nearly 2000 stars, many seemingly beyond the range of optical telescopes, and a new telescope will observe and investigate stars at greater distances. Instruments for special purposes will also be installed. The work will be largely complementary to that with the paraboloid radio telescope at Manchester University.

International Geophysical Year

THE Royal Society has announced further details of the researches for the International Geophysical year, 1957–58, referred to in these columns on January 21st last. The studies will cover meteorology, geomagnetism, aurora and airglow, the ionosphere, solar activity, cosmic rays, glaciology, seismology, gravity measurements, oceanography, and longitudes and latitudes in respect of small variations affecting the accuracy of time signals. Eleven nations are giving material assistance in setting up nearly twenty stations in Antarctica, and the United Kingdom will establish a station near Vamsel Bay, at the head of the Weddell Sea, to be working by early 1956. This station is in the North to South Pole zone passing through the Americas and Graham Land.

Research in the Upper Atmosphere

THE Royal Society announces that its Gassiot Committee, in co-operation with the Ministry of Supply, is initiating a programme of research at altitudes of 120 miles or more. Five university research groups, from the Imperial College and University College, London, the University of Birmingham, Queen's University of Belfast, and the University College, Swansea, will participate. their work being co-ordinated by a special sub-committee of the Gassiot Committee. The first experiments are intended to include determination of atmospheric temperature and density, study of the nature of the ionosphere, a search for very fine meteoric dust below 60 miles altitude, and determination of the heights of the regions from which the night airglow is strongest. It is hoped to have available within two years rockets able to carry instruments weighing 100 lb, and development of instruments will be proceeding during this time.

Purification of Brackish Water

WE are informed by the Department of Scientific and Industrial Research that Great Britain has joined an international scheme for research on desalting saline waters by electrodialysis. The work will be carried out in the Netherlands. Talks on the possibilities of various methods of desalting water have been going on for some time under the auspices of O.E.E.C. One promising process is electrodialysis—the removal of salts from a liquid flowing between pairs of ion-selective membranes, by means of an electric field. Research on this method is already well advanced in the Netherlands. The Dutch recently offered to carry out development work in co-operation with other countries showing an interest. Great Britain has joined the Netherlands, South Africa, Australia and Algeria (representing France) in paying for this work and it has now begun. The problems to be solved are mainly those of bringing up the process from small to large pilot plant scale. All the co-operating countries will share in the new knowledge and any patents that may be taken out in the future. Results which the previous Dutch work produced will also be shared between them. Manufacturing rights in any large-scale process will be available to British industry on reasonable terms. In this country an Admiralty team has been working on scale and foam prevention in methods of distillation, a well-established process. Outstanding results have been achieved in the Navy but the Admiralty, of course, has been working with sea-water exclusively. The D.S.I.R. has now given £5000 to pay for an extension of the programme to cover other waters. Scale formation is a major snag in distillation and its prevention would bring the cost down. A Dutch scientist is joining this team. Two other processes, which the French have put forward as possibilities for co-operative research, are in the exploratory stage. They involve certain aspects of ion-exchange and of solar distillation, which may be suitable for use in very hot, dry areas.

Some Physical Aspects of Lubrication in Rolling Bearings and Gears*

By W. LEWICKI, M.Sc.†

No. II—(*Concluded from page 178, August 5th*)

The author's hydroelastic lubrication theory (Lewicki, 1954) is checked by experiment. A very good agreement is found, over the whole range of rolling velocity and Hertzian stress so far covered. The film thickness (order 10^{-4}cm) is deduced by computation from the measured mutual inductive capacitance of the bounding surfaces, while in motion under load. A low-voltage radio-frequency signal is used, in conjunction with a fast cathode-ray oscillograph and a resonance circuit tuned to a harmonic. In the course of preparatory experiments several new phenomena have been observed. Coupled together with other clues found or known before, these rather unexpected new phenomena have led to the formulation of a set of distinctive properties of these films, and to a better general understanding of this mode of lubrication. It is found that the effective film viscosity (on the constant viscosity principle) is related directly to the temperature of the bounding surfaces by its usual temperature-viscosity relation; so far it appears unrelated at all to the Hertzian stress or lubricant bath temperature. It is found that the fluid films in question have no driving power whatsoever—that is to say, a freely rolling element under load tends to slide extensively in preference to rolling. This is due to the fundamental mechanism of film-forming action; the sliding is spontaneous and unavoidable unless it is externally checked. It is also found that unless this spontaneous sliding is checked the film is not only much thinner, but also subject to a disturbance, which is not as yet well understood. Much the same happens if atmospheric air is allowed to enter the Hertzian zone in the form of minute bubbles. The tendency to form such bubbles is more or less universal to all liquids and no means could be found to check it, except by a complete immersion including the surroundings. The mere delivery of enough lubricant to build up the film (a minute amount) is found problematic even at quite moderate operating velocities (1m per second) when there is some air around, a distinct problem from that of the air bubbles.

Experimental Part: Air Bubbles

IT took the present writer about a year of experimental work on the general subject of measuring the film thickness with mineral oils to lay hand on the effect of air bubbles and their interference with the formation of these films. It is easy to show the effect by experiment; two or three mils of air per litre of lubricant is enough to produce a marked thinning of the film. Unfortunately, the inductive capacitance method does not lend itself well for any precise measurements when air bubbles are present. The main reason is that the bubbles affect the overall film permittivity. Apart from that, the C.R.O. picture tends to be blurred by a form of tunnel-effect short-circuits of high frequency, perhaps due to the field emission precipitated by the thermal ions from the bubbles playing the role of hot spots when suddenly compressed to, say, 10,000 atmospheres.

D.C. Resistance of the Film

An early form of apparatus built for the measurement of film thickness by this method was, in essence, a solid cylinder of brass 4cm diameter, run against the rim of an aluminium alloy "V"-pulley 10cm diameter of a variable speed d.c. motor. Both surfaces were ground and polished to a high degree of accuracy by optical methods.

The roller was supported to rotate freely in its axis and spring-loaded against the pulley to an adjustable extent, between about 0·25kg to 100kg per centimetre of the line of contact. Sporadic lubrication by dripping was used. An adjustable d.c. potential 0·0001V to 1V was applied across the gap and the resulting current measured with a sensitive ammeter.

Almost at once it became obvious that some anomalous effects were present. The film resistance was found virtually zero, down to 0·0001V across the film, the effect not at all sensitive to speed or load over the range 0–500 r.p.m. of the pulley. Another clue was found as follows: In order to avoid any damage to the delicate surfaces by inertial skidding the operating velocity was being run up or down quite slowly. In spite of this the skidding and damage would occur, on running up the speed beyond about 500 r.p.m. It was an unexpected type of skidding, an apparently sudden slackening of the grip between the surfaces, the roller slowing down swiftly and in a continuous manner to a creeping pace. Most peculiarly, the effect was not at all load sensitive in the right sense, as one would expect it with dry friction. Namely, the more load applied the faster the slackening would progress.

Incidentally, this phenomenon gave rise to the theory of hydrodynamic skidding, to be described elsewhere. However, it was also noticed that while the skidding takes place there appears a slight film resistance, say, a 10^8th of the expected value. This gave the clue that perhaps the slight observed resistance is only a variation of an ever-present effect and that skidding may always be responsible for the anomaly, although at low velocities it may conceivably degenerate into a form of imperceptible creep.

Eventually, it was decided not to set up any specific experiments on the creep or skidding for the time being, but to build another instrument for the film thickness measurement, incorporating some mechanical means with which any form of skidding can be prevented. Accordingly, the new apparatus had a pair of toothed gears and a pair of rollers, with their diameters made equal to the respective pitch diameters. In other aspects this instrument was like the first, except that the cylinders were of mild steel, 5cm and 6cm diameter and 3cm wide, rigidly coupled to the inter-meshed gears and insulated from each other and from the gears. A markedly greater film resistance was found, although still only about a millionth of its expected value, say, up to 100 ohms as against the order of 100MΩ by equation (23) *ante*.

This work has led to the investigation of air interference, as already mentioned. Eventually, another apparatus was built, giving a positive control over the amount of atmospheric air present, as well as the extent of skidding. Ultimately, this instrument was used for the film thickness determination by the capacitance method; details of its construction are given below.

A typical voltage-resistance curve observed with this instrument, with all air excluded and skidding checked, is shown in Fig 3.

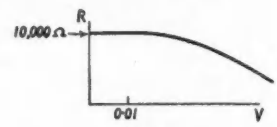

Fig. 3

The horizontal straight portion of the curve is short but obvious, showing that there is no likelihood of any extensive short-circuits in this region. The curved portion is long and not at all abrupt, as if the resistance were to break down momentarily, at an increasing frequency or duration of the tunnel effect.

The straight-portion resistance was found up to 10,000Ω, as against the predicted order of 100MΩ. An interesting possibility of solving this anomaly is by considering the effect of high frequency random field fluctuations, due to surface asperities on the one hand, and to various stray particles suspended in the lubricant on the other. The gap being of the order of 10^{-4} cm, particles down to 0·1 micron would have a definite effect on the measurement, either by a local change of permittivity or, if they are conductive, by a material reduction of the gap and increasing the field intensity.

The induced random E.M.F. component ordinarily would have no effect on the d.c. measurement, if the gap was sufficiently large to avoid sparking and the "random frequency" sufficiently low to make the field conservative and the process reasonably without loss. The fact that there is a large drop of resistance suggests that the actual field is associated with heavy losses, perhaps amounting to what can be described as diffuse sparking. The effect need not be noticeable on the C.R.O., as the effective overall resistance would be the summation of transients, each requiring a relatively long period of time to re-establish itself while the ionisation resulting from what is in effect a short circuit is being dissipated. While the resistance rises and presumably long before it reaches its peak value a new breakdown occurs at some other spot between the surfaces, &c. The overall picture would be a steady low resistance, even though the breakdown frequency may be within the resolving power of the C.R.O.

Film Capacitance Method—Apparatus

The apparatus capable of measuring what is believed to be the true film thickness in a rolling-contact mode of lubrication is shown in Fig. 4 in axial and transverse section.

Two rollers 1 of hard brass, 39mm dia. (top) and 46mm dia. (bottom), both 31mm overall width, are suspended in a thick-walled "Perspex" box 2 by four sliding bearings 3, 6·3mm dia. The bottom bearings are fixed to the walls of the box and the top ones slide between runners 4 and take up the external load by the beam 5 and sliding

* This article is a copy, with some minor additions, of the author's thesis approved for the award of the M.Sc. Degree in Physics by the University of London. The University has also given permission for publication.

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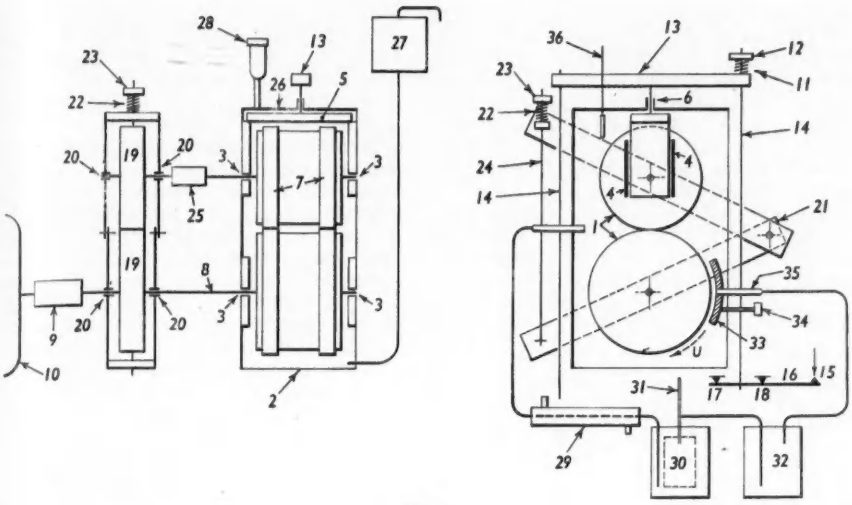

Fig. 4

pin 6. The line of contact is 6·35mm wide, subdivided into two equal portions 7. The portions are well spaced apart and their length is determined by the width of sharp-edged rings of the bottom roller, the rings of the top roller being a trifle wider. The rings protrude 1·6mm over the body of their rollers, so that the inactive parts are well recessed. The steel shaft 8 of the bottom roller is coupled by the insulating block 9 to a variable speed d.c. motor 10.

The external load is applied by the spring 11 and nut 12 to yoke 13 and pin 6, the yoke being held by tendons 14. The pin 6 is placed centrally in relation to the rings 7. The external load is determined by placing weights over the pin 15 of the lever 16 as shown with an arrow. The lever balances the pull of the tendons 14 against the stop 17, and is held in position by the stop 18.

The discs 19 of brass, 5mm wide and equal diameter to the respective rollers, are fixed to their shafts and held by the sliding bearings 20. The purpose of these discs is to arrest sliding, i.e. to drive the top roller by friction. The bearings 20 are held by the double V-fork 21 and are pre-loaded by the spring 22, nut 23 and tendon 24. The latter is placed centrally in relation to the discs, so that their load does not communicate to the rollers. The top roller is insulated from its disc by the ebonite block 25. The discs are normally kept dry, but can be lubricated and their load relaxed, to allow for a free motion of the top roller.

The rubber-sealed cover 26 allows the box 2 to be filled with lubricant so that all atmospheric air is excluded and the fluid kept under a slight pressure by placing the reservoir 27 above the box. By placing the reservoir at a lower height, any desired volume of air can

Fig. 5

be made to enter the box by the dust-proofed overflow 28. When operating, the oil is circulated in a closed circuit through the water-jacket cooler-heater 29, parachute-silk bag-filter 30, with the manometer 31, and through the bulk reservoir 32. The oil is driven at about 1 kg/cm² on the manometer by the floating pad 33 used as a pump. The pad fits the recess between the rings 7 of the bottom roller, and is asymmetrically supported by the pressure-adjusting screw 34. When the roller rotates, as shown with an arrow, a fluid wedge is formed under the pad, and the pressurised oil escapes to the circuit through the hollowed gland 35. The bath temperature is measured with the thermometer 36 graduated at 0·1 deg. Cent. intervals. P.V.C. tubing, 9mm dia., is used in the circuit.

Electric Circuit

The mutual capacitance of the rollers, $C_0=C+C_s$, where C is given by (36) and C_s by (37), is measured by the resonance method shown in Fig. 5. The rollers C_0 are in

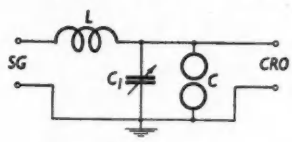

Fig. 6

parallel with a calibrated capacitor C_1 and the inductance coil L, the whole tuned to resonate at the arbitrary frequency 198 *KC*, and fed from the signal generator *SG* tuned to a half of that frequency. There results in the resonant circuit a voltage ripple of the type *a* in Fig. 7, which is fed into the cathode ray oscillograph *CRO* and is made visible.

The expedient of tuning to the second harmonic is used, first, to increase the selectivity of C_1, secondly, to avoid the resonance voltage surge. The effect can be judged by eye as the oscillograph usually shows the signal wave as well as the track *b* in Fig. 7, which is super-

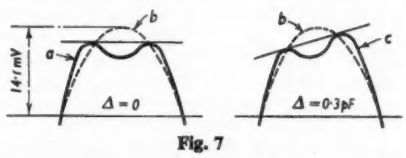

Fig. 7

imposed on the track *a*. It appears because of the short-circuits between the rollers which occur sporadically and hamper the oscillations of the circuit. In order that C_0-measurements be reliable, the short-circuit track on the oscillograph should be kept faint in comparison with the track *a*. The harmonic interference causes only a slight fall of the voltage peak of the signal during the observed half-wave and an equal slight increase along the other half-cycle.

A change in C_0 causes the ripple to shift sideways and to take up a slanting position, as *c* in Fig. 7. By compensating with C_1 the ripple is brought back to level. The difference in the C_1 readings gives the change in C_0. The method is easy to carry out and is accurate to within, say, 0·15pF, without any added refinements.

The circuit values are: C=20pF to 80pF, C_s=23·1pF, C_1=25·7pF to 160·8pF, L=4·5mH. Signal 0·010V, r.m.s.

The circuit, Fig. 6, was tried but not used, because of its phase relation being different from that of Fig. 7. It has the advantage of a somewhat greater stability because of the earth in the tuned circuit; it also enables direct readings of the potential difference across the gap to be made. The lack of earth in the first case makes it necessary to handle C_1 through an insulating extension at least 20cm long.

Procedure

At the outset of trials with the instrument the capacitance readings were found unpredictable and erratic, in spite of carefully keeping the oil temperature at a constant level, &c. The writer noticed that, first, the readings were extremely sensitive to what was taking place in the instrument a minute or two before; secondly, directly after a run the bath temperature would peculiarly rise by a degree or two. It soon became apparent that the film viscosity depends on the body-temperature of the rollers but not at all on the oil bath temperature or Hertzian stress.

It is understandable why the rollers should tend in operation to become hotter than the surrounding bath, in spite of the fact that all sliding between them is suppressed. The inter-layer friction is mostly confined to the Hertzian zone and the adjoining portion, comparable in size, of the inflow region. Although the volume of the generated heat is relatively small the combined zone is an intense heat source, due to its small size. While the heat is produced the fluid is brought very intimately in contact with the surfaces, and so the heat mostly dissipates into the body of the rollers.

In order not to introduce any new variables in this connection for the time being, the following procedure was adopted. To start with, the apparatus was run slowly and hot or cold water passed through the jacket 29, bringing the bath temperature by the thermometer 36 to about 0·5 deg. Cent. above the value at which the capacitance reading was to be taken. Then the instrument was stopped and kept slowly cooling by external dissipation through the Perspex walls for five to ten minutes, thus making all temperatures within the box even to, say, 0·1 deg. Cent. On reaching the right temperature the apparatus was suddenly put to run at full required speed and the capacitance reading taken, within, say, ten to thirty seconds from the start, depending on the range of load, velocity, &c. Immediately afterwards the revolutions per minute reading was taken and the apparatus stopped.

Readings to 4000 r.p.m. were taken by this method at light loads, say, 5kg to 10kg on the top roller, and to 1500 r.p.m. at higher loads.

Results

So far three sets of consecutive capacitance measurements have been taken; they are plotted against velocity as series (*a*), (*b*) and (*c*) in Fig. 8. All these measurements are for brass rollers and a machine oil, with traces of paraffin, at 27 deg. Cent. The difference between the cases (*a*), (*b*), (*c*) is only in the external load; in each series the load and the bath temperature are kept constant and only the operating velocity is varied. The

slip between the rollers is always suppressed as far as possible with the external frictional discs and all atmospheric air is excluded from the lubricant bath. In this way the overall range in S so far explored is covered consistently, that is to say, with as few variables as possible.

Together with the observed capacitances and the resulting mean observed capacitance curves, Fig. 8 also shows the corresponding expected capacitances, by equation (36). Actually two sets of the theoretical C points are given, joined together into the "upper" and "lower" theoretical curves (*a*), (*b*) and (*c*). The computed points are marked in Fig. 8 with the value of the parameter S at which the capacitance and operating velocity were computed and with the series number. The "upper" and "lower" curves are of the type parameter=const., they represent the likely upper and lower extreme of the parameter values and for identification they are marked with the value of the constant parameter.

The expedient of twin theoretical curves is used in order to form expectancy regions, over which the observed capacitances are to be plotted with the idea of interpolating the various quantities required from known boundary values. This procedure could be avoided by constructing unique curves if the anticipated complete physical correlation of the parameters was known. This is, of course, not the case. At least, the already mentioned relations for very thin and very thick films, respectively $\alpha=2\cdot618$ and $H=1$, call for an experimental verification. Besides, the observed shape of the correlation for the intermediate values of S as well as all other required quantities can be evaluated by interpolation, such as, for instance, the minimum film thickness by (12) and the Hertzian stress by (25).

The assumptions and other data used in constructing the curves are listed below. The device of a treble "U"-scale in Fig. 8 is, of course, used to spread out the curves as they otherwise overlap and make a confused picture. The procedure of finding the theoretical points is somewhat laborious as it involves the use of (8) for the third parameter, (28) for the function B, (27) for U as well as (36) for C.

Fig. 9 gives graphically the expected values of h_1 by (12). The computed points are marked with the value of S and the series letter. The correspondence with Fig. 8 is shown by marking the resulting curves with the constant parameter value. Note that the α=const. curves are unique, i.e. common to (*a*), (*b*), (*c*). It is because theoretically—that is to say, by (12)—the film thickness is independent of load if α=const.

In Figs. 8 and 9 to all points of the regions correspond unique parameter values as well as unique C, h_1 and P. Hence, e.g. the graphs Fig. 9 can be used to plot h_1=const. curves in Fig. 8. Such h_1=const. curves would join the corresponding boundary values and in the first approximation they would be straight lines crossing the regions. In principle, in this way the film thickness could be read directly against the observed capacitances. Conversely, the observed capacitances could be plotted in Fig. 9 with the help of Fig. 8. Of course, the three regions of Fig. 9 are overimposed and for such a plotting it would perhaps be better to draw each separately, as Fig. 8.

Neither of these cross-plottings is introduced at present in order not to obscure the graphs. Besides, the attained experimental accuracy (see below) is insufficient to justify evaluating the small differences involved. These differences are discussed in the next paragraph.

The "upper" curves of Fig. 8 are calculated on the assumption of $\alpha=2\cdot618$ from $S=0$ to $2\cdot472$, i.e. by (8) from $H=0\cdot2361$ to 1, and the assumption of $H=1$ for $S\geqslant2\cdot472$. For the "lower" curves, $\alpha=2$ from $S=0$ to $0\cdot71$ ($H=0\cdot1716$ to $0\cdot3$), and $H=0\cdot3$ for $S\geqslant0\cdot71$. The regions H=const. have, of course, α varying by (8).

The data used in the calculated values are: bath viscosity $6\cdot34$ poise at 27 deg. Cent., density $0\cdot8996$, permittivity $2\cdot19$, $K=0\cdot4630\text{cm}^{-1}$, all of which were measured; the elastic constants for brass, $E=1\cdot118\times10^6\text{kg/cm}^2$, $\sigma=0\cdot340$, where taken from Marks' Handbook, page 423, ed. 1941. The external load, $N_0=19\cdot87$kg/cm for series (*a*), $40\cdot50$kg/cm for (*b*), and $95\cdot94$kg/cm for (*c*). The corresponding Hertzian stress for stationary rollers,

$$P=\sqrt{\frac{KEN_0}{\pi(1-\sigma^2)}} \quad . \quad . \quad . \quad . \quad (43)$$

is 1924kg/cm² for (*a*), 3461 for (*b*), 4228 for (*c*). In operation this stress somewhat decreases. We obtain P from (25); along the "lower" curves it is 1577kg/cm² for (*a*) at $S=4$, 3019 for (*b*) at $0\cdot71$, and 3816 for (*c*) at 0. The stress along the "upper" curves is 4 to 8 per cent higher at the same velocity, except for (*a*), whose anomalous behaviour is discussed in the next paragraph.

The low-speed limit for readings was set by a virtual disappearance of the ripple pattern on the *CRO*, because of short circuits. It was somewhat load sensitive, say, $U=0\cdot82$m/s for (*a*) and $0\cdot92$ for (*c*), but occurring at much the same film thickness, about $h_1=0\cdot5\mu$ (micron, $1\mu=10^{-4}$cm $=10^4$Å). The greatest film thickness measured was about $1\cdot5\mu$ for (*c*), $1\cdot6\mu$ for (*b*) and $2\cdot5\mu$ for (*a*). The three series together cover the range in S from 0 to about 15.

Estimated errors are: absolute observed capacitances ±2 per cent; relative capacitances ±3 per cent, except for the end portions

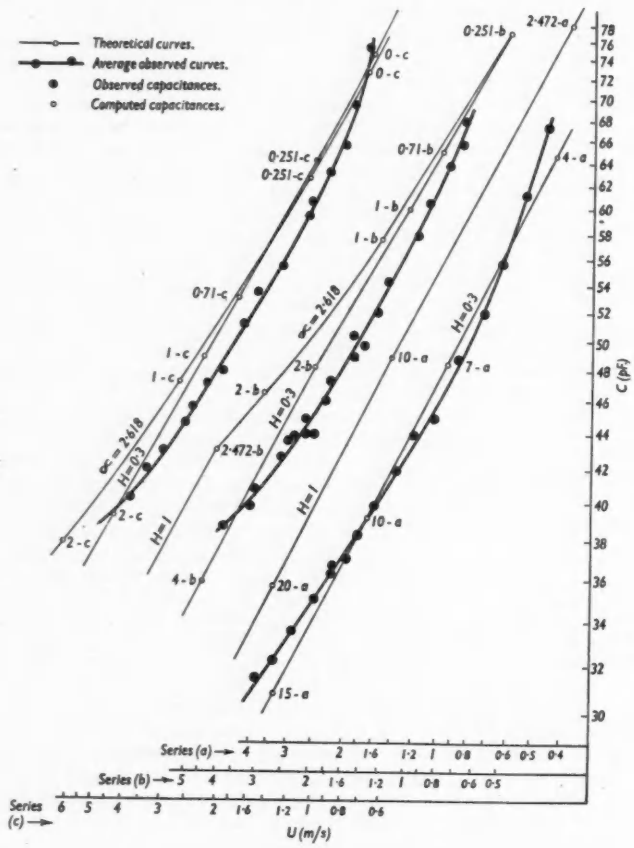

Fig. 8

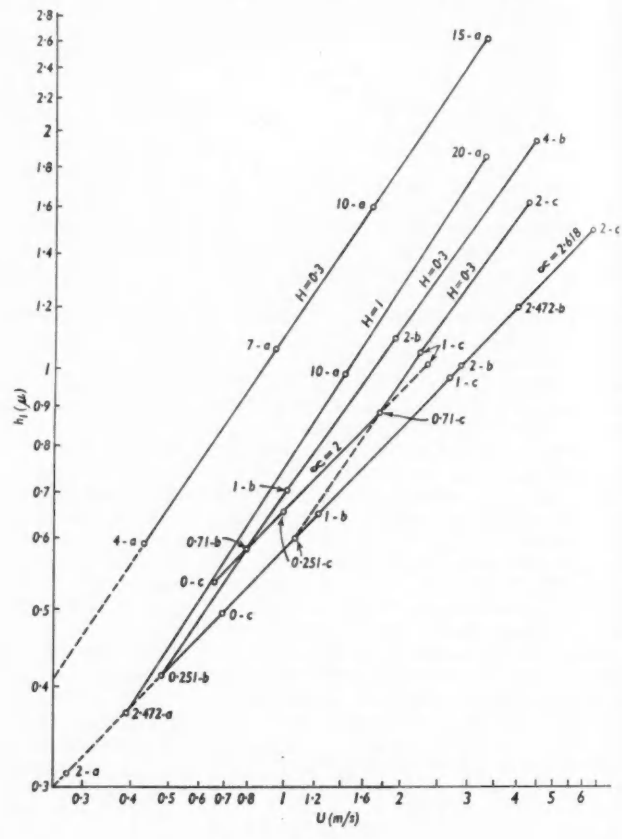

Fig. 9

of all series where the error can be somewhat greater ; computed absolute values ± 2 per cent ; overall experimental error ± 7 per cent.

Conclusions

Assuming that the " upper " and " lower " theoretical curves of Fig. 8 represent the extremes of the possible values of the parameters α, H, S, we expect the observed values of C to lie in the region between them. If they are not, it is not unlikely that the constant-viscosity postulate breaks down. From the aspect of Fig. 8 it would appear that the true effective film viscosity (under the assumption η=const.) is slightly greater than postulated—that is to say, it refers by the usual temperature-viscosity relation to a slightly lower temperature than the body temperature of the rolling elements. However, the deviation does not exceed 6·8 per cent, which is just about within the experimental error. So, one cannot say with certainty whether there is a deviation, but, at any rate, it cannot be appreciable.

It appears that the " lower " theoretical curves, Fig. 8, fit the true values better than the other curves, except perhaps for $H \to 1$ when $S > 15$. Although the series (c) does not warrant discrimination as the curves are largely coincident in this region of S, the argument for $\alpha \cong 2$ when $S \cong 0$ is supported on theoretical grounds. So far, there is no evidence against $=2 \cdot 618$ when $S \to -1$. However, it must be pointed out that the value 0·3 for the H=const. part of the " lower " curves has been chosen arbitrarily, to fit the observations.

Note that the film thickness along the " upper " curves is smaller than for the " lower " curves at the same speed. The difference is nearly constant at about 10 per cent of the larger value from S=0 to 0·71 on the " lower " line, it then gradually increases to about 30 per cent at S=2·472 on the " upper " line, after which it remains fairly constant at that value. So, if other arguments are put aside, the lack of discrimination in the low region of S is not likely to cause an error in h_1 in excess of 10 per cent of the larger value over the experimental error, and 30 per cent with thick films.

The P/U curves (not shown) by (25) have the expected slight downward trend with U increasing, except for the case (a) and a portion of (b) along H=0·3, where there is an anomalous upward trend. This would indicate a disagreement with the hydroelastic approximations used and the existence of a measure of error in all theoretical curves which becomes obvious at small values of the film ratio α. Another indication of these disagreements seems to come from the lack of any more definite convergence towards S increasing between the H=1 and H=0·3 branches in Figs. 8 and 9. The point is that the effect of H on the capacitance should, in principle, tend to become negligible for thick films.

However, from the general aspect of Fig. 8 it is apparent that the theoretical error in h_1 is not in any way extensive. At any rate, an increased convergence would make the H=0·3 curve fit the observations better if anything. However, it may well be that the high speed end of the observed curve (a) tends towards the H=1 curve partly because of an increased experimental error in this region. Note that the two other observed curves also show this tendency.

The upward bend at the low-speed end of all observed curves may include the contribution to the capacitance by the surface asperities, but certainly most of it is again due to an increased measurement error. No proper molecular surface effects can be expected, the range of molecular forces being, say, 10Å, and the least film thickness 5000Å. Of course, if the lubricant contains hard particles larger than 5000Å, there would be sporadic effects of this nature, followed by local small-scale film breakdowns, &c.

Unless some refinement is added, the present method does not permit the evaluation of the shape of the bounding surfaces within the Hertzian zone to check on the assumed configuration of Fig. 2. It is more specific for an average film thickness along the Hertzian zone than for its minimum, &c. For instance, if the shape of the elastic depression proves to be somewhat concave and not flat, the true h_1 would be somewhat less than computed by Fig. 2 from the observed capacitance.

Literature

No useful experimental data on rolling action seem to exist in the literature. The attempts to measure the film thickness in gears by an ohmic resistance method, such as for instance Cameron's (1954) or Lane and Hughes's (1952) did not result in any numerical data. The authors apparently did not measure the temperature of the rolling elements (gears) ; it must be borne in mind that something like a ten-fold drop of viscosity could have resulted from, say, 40 deg. Cent. rise. Again, the authors do not appear to have taken any precautions to remove conductive particles which might have strayed into the lubricant.

Apart from these and similar minor objections, these methods, including the use of thermo-electric effect, are all questionable on fundamental grounds, because of the introduced transients. The Cameron's method is particularly so ; he forces a high-density current through the film, say up to 300A/cm of the contact line, amounting to perhaps 10,000A/cm² of the Hertzian zone surface. The volume of the passing fluid is, of course, very small at any reasonable velocity, so that the film is most likely being exploded ; whatever he measures, it is certainly not the film thickness.

Incidentally, the Cameron's pioneering experiment has an unexpectedly gratifying outcome, as it shows that the lubricant film can act as well in an exploded condition as a highly pressurised gaseous pocket. There is apparently no immediately noticeable effect on the frictional behaviour and surface wear.

The general-purpose measurements on ball bearings by Fogg and Webber (1953) are not furnished with sufficient data and are generally too superficial for the present use. A somewhat related investigation by Courtney-Pratt and Tudor (1946) on piston rings by a resistance method, extensively quoted by Bowden and Tabor (1950), does not really prove the existence of the periods with no substantial film, contrary to what the authors say. Sporadic short-circuits by stray particles of sub-microscopic dimensions could as well have been responsible for the patterns in their oscillograph pictures.

In the theoretical field, Cameron (1952) mentions the possibility of the film thickness being independent of load, and in this connection refers to C. Weber (1950) and in his later article (1954) to a private communication to him by J. Dörr. Mills (1954) mentions the possibility of measuring the film thickness by capacitance.

Acknowledgments

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British Association's Meeting at Bristol

The 117th annual meeting of the British Association for the Advancement of Science is to be held at Bristol from August 31st to September 6th. It will be the fifth such meeting to take place there, the former occasions having been in 1836, 1875, 1898 and 1930. The president this year is Sir Robert Robinson, O.M., F.R.S.

The first general assembly of members at this year's meeting will be on Wednesday evening, August 31st, in the Colston Hall, Bristol, at 7.45 for 8.15 p.m., when honorary degrees are to be conferred upon the president and Professor N. F. Mott, F.R.S. Sir Robert Robinson will then deliver his presidential address entitled " Science and the Scientist."

The sectional meetings will begin on Thursday morning, September 1st, and those of Section G, Engineering, are to be held in the University Engineering Building. The president of the section is Dr. S. F. Dorey, F.R.S., and his address, which will be delivered at 10 a.m. on September 1st, is entitled " The Influence of the Engineer on Sea Transport and Trade." It will be followed by a paper on " The Influence of Space Flight on Engineering and Science," by Mr. M. W. Rosen. On Friday morning, beginning at 10 a.m., the papers to be discussed are " Model Research and its Application to Ship Design," by Dr. R. W. L. Gawn ; " The Scientific Development of Modern Locomotive Designs," by Mr. J. S. Tritton and Mr. J. C. C. Paterson ; " The Methods of Using Fuel in a Nuclear Power Programme," by Dr. J. V. Dunworth, and " The Design and Operation of Power Producing Reactors," by Mr. H. H. Gott. On Monday morning, September 5th, there are papers on " Motorways," by Mr. J. A. Proudlove ; " Motor Vehicles and Design," by Mr. J. N. McHattie ; " The Linear Acceleration of Charged Particles to High Energies," by Mr. C. W. Miller ; " Circular Accelerators for Nuclear Particles," by Dr. J. B. Adams, and a series of papers dealing with various aspects of soil mechanics. On Tuesday morning, September 6th, the papers arranged for Section G are " Recent Progress in British Air Transport," by Mr. Peter Masefield, and " Effects of Turbine Engines on Civil Air Transport Design," by Dr. W. J. Strang. In addition, there are four papers by young engineers as follows :—" The Effect of Leakage on Compression and Expansion in a Non-Flow Process," by Mr. D. L. Brook ; " Collapse Tests of Vierendeel Trusses," by Mr. S. Henderson ; " A Mathematical and Photoelastic Investigation of the Stress Distribution Under Foundations," by Dr. J. E. Gibson, and " Constraint Effects in Box Beams," by Mr. D. Howe and Mr. K. H. Griffin. The afternoons during the meeting, and the whole of Saturday, September 2nd, are to be devoted to visits to works and other places of interest in and around Bristol.

Joint Metallurgical Societies' Meeting in Europe

No. II—MEETINGS IN FRANCE

(*Continued from page 183, August 5th*)

During June the Iron and Steel Institute and the Institute of Metals organised a Joint Metallurgical Societies' Meeting in Europe which was attended by representatives from this country, Belgium, France, Germany and Sweden, and attracted across the Atlantic a large number of Canadians and Americans. Our American Editor attended the meeting and we arranged that he should report upon that part of its proceedings which took place on the Continent, in the belief that it would interest readers here—and on the Continent—to learn what, in particular, would attract the attention of one familiar with American practice.

Official Receptions

THE final part of the Joint Metallurgical Societies' Meeting was held in France from June 14th to 18th, and was organised by the Société Française de Métallurgie. At the opening plenary session, held at the Sorbonne on Tuesday, June 14th, the delegates were welcomed by Monsieur Raoul de Vitry, president of the Société Française de Métallurgie. Subsequently, a lecture entitled "French Contribution to Metallurgy," was delivered by Professor Paul Bastien, director of scientific research of the Ecole Centrale des Arts et Manufactures. As this lecture gave a particularly interesting account of certain current metallurgical developments in France, we are presenting an abstract below.

Following the opening session at the Sorbonne, the delegates were officially received at the Hôtel de Ville de Paris by the President of the Council and the Paris Municipality. In the evening there was a reception by invitation of the Société Française de Métallurgie at the Musee du Louvre. After a tour of the well-known masterpieces of sculpture assembled at this museum, members and their ladies were entertained most lavishly at a champagne supper.

French Metallurgy To-day

Reverting to Professor Bastien's lecture, we wish to mention the more important developments in current French metallurgical practice which were touched upon in it. In the field of iron and steel it is, of course, well known that Bessemer's invention of the acid converter made possible the working of the phosphorus ores of Lorraine. Open-hearth practice in France goes back to 1865, when Martin obtained his patent. The use of a basic furnace-lining for what used to be the initially acid Martin lining, permitted dephosphorisation as well as the use of impure charges. In the field of electric heating, the arc and high-frequency furnaces now play a fundamental part throughout the production of high-quality steels and alloy steels. Reactions between the metal and the slag during iron and steel processing have been very thoroughly studied throughout the world, both in theory and in practice. Such studies have recently, in France, led to a rather original application in which melted steel is poured with turbulence into a ladle containing, in its lower part, a slag whose composition, temperature and fluidity are properly chosen. The resulting technique, known as the Ugine-Perrin process, is now extensively used, and the first ladle processing through liquid slags was carried out in 1930. The aim was a rapid, automatic and consistent manufacture, through medium-size melting apparatus, of steels with specific characteristics: a low oxygen and sulphur content, freedom from inclusions and good mechanical qualities. The Ugine-Perrin process, applied originally to steel from the electric arc furnace only, has now been extended to the Martin open-hearth furnace, and also to the Thomas converter. This latest application to metal from the Thomas converter becomes all the more interesting when one remembers the importance of the phosphorus ores in the French iron and steel industry; one of the aims of such an application is to produce from Thomas converters killed steels meant for hot and cold continuous rolling mills to be processed into sheets for deep drawing purposes, including motor-car body sheet stock.

While in the field of plastic deformation of steel, relatively little new work has been done in France as regards continuous rolling mills, one important development in hot steel extrusion is the invention of Séjournet and Labataille to place between the metal and the die the appropriate lubricant made up of a mixture of silicates, possessing characteristics similar to that of a glass. The billet, coated through capillary adhesion with a viscous cover, is easily extruded under this protecting and lubricant film.

The important historical French contribution to the metallurgy of aluminium is well known: the first industrial production of aluminium is due to Henri Sainte-Claire-Deville, who, in 1954, obtained the metal in ingot form through the reaction of sodium upon aluminium and sodium biochloride of aluminium; the first ingots were presented in Paris at the 1855 Exhibition. Subsequently, Sainte-Claire-Deville obtained aluminium through the electrolysis of anhydric chloride, and during this work he noted that alumina dissolves easily into smelted cryolite. In advocating the preparation of aluminium by the electrolysis of a smelted mixture of alumina and cryolite, Heroult, in France, and Hall, in the U.S.A., established finally the metallurgy of this metal. Throughout the electrolytic process the quantity of alumina dissolved into the cryolite must be kept at a constant level, and as far as consumed material is concerned, it is the alumina which plays the essential part. It was, therefore, logical to use an ore particularly abundant in France — bauxite or hydrated alumina. Bauxite has to be purified and dehydrated: Sainte-Claire-Deville proposed a purification process which came into industrial use until a more simple method came about; a foreign one, the Bayer process, took its place. With regard to electrolysis itself, the multi-electrode cells have been gradually in receding use, being replaced by cells equipped with round electrodes of the Soderberg type. Tackling the problem anew, the Riouperoux plant, in the French Alps, had the idea to replace the round electrodes with rectangular ones. The tests were carried out successfully and enabled the production of cells employing an electric current up to 100,000A. Nowadays, two-thirds of the aluminium produced in France comes from rectangular electrode cells.

Finally, in the field of industrial development of metallurgical theory, two recent French contributions are worthy of note. The systematic study of the characteristics of the anodic dissolution of metals has led Monsieur Jacquet to electrolytic polishing, which is now resulting in surfaces with a very fine polish, without any disturbance being caused by mechanical action. Originally developed for light alloys only, this process has now been extended to all alloys and to steels. In the same way, though in quite another field, Professor Neel, from theoretical notions of physics involving the dimensions of Weiss's elementary ranges and the possibility of their walls being displaced, has led to thoughts that extremely finely ground iron powders should hold, after proper magnetisation, a high remanence and coercive force. These ideas have been confirmed by experience, and have brought about the production of permanent magnets made of pure iron powder.

Persan

In view of the importance to-day of the hot extrusion process, many delegates regarded the visit to the works of the Comptoir Industriel d'Etirage et Profilage de Metaux, at Persan (Seine et Oise), as one of the major events of the French session. While relatively small in size, the works nevertheless constitute an excellent illustration of the production potential inherent in the Ugine-Séjournet process of hot extrusion of steel tubing and sections.

The production of steel bars, shapes and tubes by hot extrusion had been under consideration in most industrial countries for more than twenty-five years and had been intensively studied by an important French steel producer, the Acieries Electriques d'Ugine. Tests conducted by this company as early as 1925 indicated that steel can be extruded under suitable conditions equally as well as many non-ferrous metals. Actual commercial operation, however, was not accomplished in view of the rapid wear and seizing of tools which usually were able to function satisfactorily for only a single operation, while sometimes not even one successful bar or tube could be obtained. These experiments were undertaken with three objectives in view. First, it was hoped to produce unbalanced solid and hollow sections of the kind normally extruded from copper and aluminium-base alloys. Such sections are frequently of a complex form that either cannot be rolled or, where rolling is possible, demand complicated rolling equipment. An outstanding example of this class of component is the tubing employed for the manufacture of hollow turbine blades. Secondly, it was considered that it would be possible to convert into the desired forms grades of steel that were so highly alloyed that they could only be rolled with great difficulty or with very low yields. Thirdly, it was believed that extrusion would permit the production of sections that could be readily rolled, but were required in such small quantities that the cost of the rolls and, in some instances, the cost of setting up, could not be justified. The extrusion of such sections would, it appeared, be economical since the necessary dies were relatively inexpensive and die changes could be effected quickly.

The Ugine Research Laboratory, which had been at work, as were many others at that time, on steels and other alloys for high-temperature service, felt that it had discovered a new composition which would be

adequate for these extrusion tools and that the original problem could thereby be solved. The first tests, however, dispelled this preliminary confidence in that the experiments by the steel works with the new heat-resisting steel were most disastrous. It was concluded that the solution of the problem had to be sought in other directions. At this time, Comptoir Industriel d'Etirage et Profilage de Metaux, a small private company engaged principally in the cold drawing of metals, was at work in Paris on the extrusion of non-ferrous metals and alloys, and had specialised in the production of unbalanced sections. Being acquainted with each other's activities resulted in a technical agreement being signed between these two companies with a view to co-ordinating their efforts in 1940. C.I.E.P.M. attacked the problem in the direction of improving the lubrication, but soon reached the conclusion that actually there was not one, but two problems in this field that required solution, namely, the lubrication between the billet and the container and between the billet and the die. Many lubricants, both those in current use and others, were tried, including materials of mineral origin as well as those produced from animal and vegetable raw materials. Neither those that were solid at the operating temperatures, nor those that were liquid, gave satisfactory results, and the latter seemed to have much too high fluidity. Furthermore, it was observed that under operating conditions materials containing carbon, instead of lubricating, appeared actually to promote seizing of the billet and the tools. They came, therefore, to the absolute requirement of carrying on subsequent experiments only with carbon-free materials and, more particularly, those melting at quite high temperature. It was these experiments that led to the discovery that glass, introduced in solid form, was a most useful lubricant and simultaneously served as an insulator, thus effectively protecting the tools from contact with the billet and with the section in course of extrusion, and also from absorption of too much heat therefrom. Later came the concept that any related substance possessing adequately high softening point and adequate viscosity at the operating temperature, and melting over a range of temperature, could supply the necessary qualities. This is the principle that has now been put into practice.

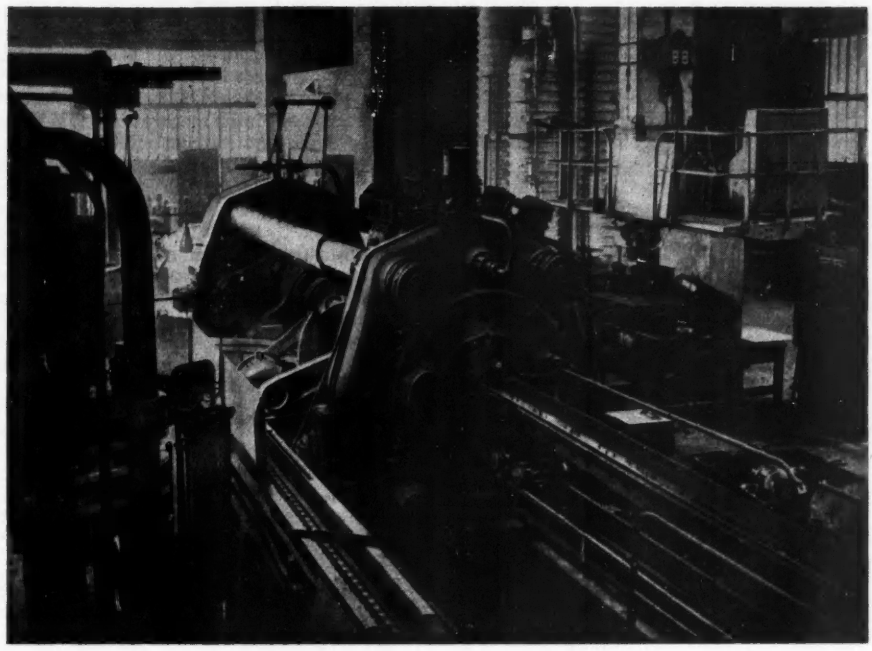

Fig. 10—1500-ton extrusion press at Persan

The Persan works were bought by the Comptoir Industriel d'Etirage et Profilage de Metaux in 1943, to set up there a wire-drawing shop able to exploit industrially the new glass lubrication processes which had been perfected at the experimental shop inside Paris. At that time the Persan works comprised several large forging shops with a total surface of 14,000 square yards. All these buildings were requisitioned by the Germans in 1943, dismantled and sent to Germany. The factory was then bombed several times by the R.A.F., and in 1944 there remained only the bare ground. Reconstruction of this factory was delayed by the post-war lack of funds and materials. It was started only in 1947 and completed in 1949. The illustrations (Figs. 9 and 10) show a general layout of the works and a view of the 1500-ton extrusion press. Essentially, the works comprise gas and electrically-fired preheating furnaces, a Morane extrusion press having a capacity of 1500 metric tons, a Morane piercing press of 400 tons capacity, a Schloemann 50-ton stretcher-detwister-straightener, a Bigwood-Hanning tube straightener, and complementary installations for pickling, conditioning and tool preparation.

The processing involved at Persan demands that the billets be heated without undue scale production and, therefore, barium chloride salt bath furnaces with plunging electrodes are at present employed for final heating. However, this technique is high in cost and different methods have been developed and are already in use in other works : e.g. low-frequency induction heating in the U.S.A. and rotating glass bath furnaces in Italy. The Persan works receives forged or rolled bars in commercial lengths. These bars are first sawed to length on one of three Sigwa billet saws, then inspected and reheated in a gas-heated continuous furnace up to a temperature which does not cause too much oxidation. The 7in diameter billets are then put into specially designed baskets and transferred into three salt bath furnaces with plunging electrodes, where their temperature rises up to about 1200 deg. Cent. Then they are given a coating of glass powder and are extruded on the 1500-ton press, the die being protected by discs of agglomerated glass powder. When the extruding operation is ended there remains in the container a small part of the ingot, called " culot " (bottom), which is sawed apart from the drawn bar. This bar is then cooled, straightened under application of tension, and pickled. In the case of tubes the processing includes a hot piercing operation on the 400-ton press and a reheating. In the case of stainless tubes, grinding of the tubes after extrusion and before shipment is required. The Persan works specialises in the production of solid and hollow profiles in ordinary steel and of tubes in stainless or refractory steels. Its production amounts to about 200 tons a month and, primarily, it should be regarded as a pilot plant which serves to determine the exact conditions under which the Ugine-Séjournet process may best be applied under mass production conditions.

It is of interest to note that licensees of the process are to-day operating in the U.K., the U.S.A., Sweden, Italy, Germany and

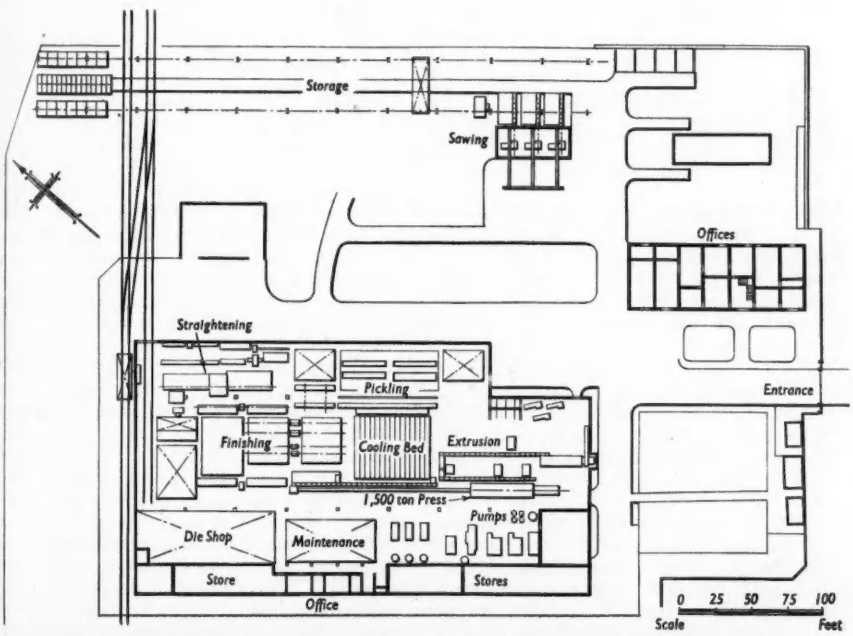

Fig. 9—General layout of Persan works for hot extrusion of steel tubing and sections

Austria. The British licensees are the Chesterfield Tube Company, Imperial Chemical Industries, Ltd., Low Moor Fine Steels, Ltd., and Henry Wiggin and Co.

At the time of the visit by the delegates, the works were engaged in the extrusion of stainless steel tubing of 91mm O.D. by 83mm I.D. by 8m approximate length, produced from 180mm O.D. by 90mm I.D. by 350mm long billets. The analysis of the steel was as follows : 0·09 per cent carbon, 0·4 per cent silicon, 1·4 per cent manganese, 11·5 per cent nickel, 17·5 per cent chromium, 2·25 per cent molybdenum, 0·4 per cent titanium, and 0·6 per cent copper. This analysis is similar to the specification No. 316 of the American Iron and Steel Institute. The tools used in extrusion were made of a 10 per cent tungsten hot working die steel.

As a result of the operation of the pilot production plant at Persan, valuable information has been assembled which is now being applied to present and future steel extrusion installations using the Ugine-Séjournet process. Experience indicated that one of the major problems encountered in the hot extrusion of steel is the effect of lubrication on total extrusion pressures. While a reliable formula giving the value of the total pressure to be applied to the billet for a given extrusion has been found difficult to establish when operating without lubricant, conditions proved simpler when adequate lubrication was ensured. It has, therefore, been possible to derive an expression whereby the extrusion pressure may be calculated, provided that the dimensions of the billet, the frictional coefficient and the resistance of the metal to deformation at the operating temperature are known. Conversely, by measuring the extrusion pressure for a given operation, it was found possible to determine either the friction coefficient or the resistance to deformation of the metal or, provided that a sufficient number of tests was performed, both of these factors. In this way values for the resistance to deformation of the various metals that have been extruded, have been calculated, and it has been found that for practical purposes the resistance to deformation, at the temperatures generally employed, is inversely proportional to these temperatures. Moreover, graphical data have been established relating to the resistance to deformation of most of the materials that can be extruded. For example, mild steel, at 1150 deg. Cent., requires a pressure of 19,800 lb per square inch ; an 18–8 stainless steel, a pressure of 27,000 lb per square inch, and an 18–4–1 high-speed steel a pressure of 37,000 lb per square inch.

It has been calculated that, without lubrication, the frictional coefficient between the billet and the container is about 0·12. When ordinary glass is used as a lubricant, the value of this coefficient falls to 0·04, and by employing a specially developed glass it may be reduced to so small a value that there is no noticeable difference between the pressures required at the beginning and at the end of the extrusion cycle.

Current operating practice based on the Ugine-Séjournet process requires that the raw material to be extruded be in the form of round ingots, either in the "as cast" or turned condition, or in the form of rolled or forged bars. The diameter of billet that may be employed ranges from about 3in for a 300-ton press, to about 16in for a 4000-ton press. Depending on the reduction in cross-sectional area that is required and the capacity of the extrusion press, the length of the billet may vary from 8in to 32in. The pressure applied by the ram of the extrusion press ranges from 80,000 lb to 160,000 lb per square inch. For a given press, when the diameter of the container decreases the specific pressure rises until a limit is reached due to the strength of the steel of which the tools are made. On the other hand, when the diameter of the container increases, the specific pressure decreases until there is not enough force to endure an economical deformation. The maximum volume of metal extruded, which controls the length of the bar of a given cross-sectional area that may be produced, is determined by the size of the billet. If the pressure in the container is low, the dimensions of the billet are controlled by the volume of the container. When the operating pressure is high, however, the billet length may, of necessity, be reduced to less than the maximum that the container can accommodate; in that case, the limiting factor is the length of the extruded bar which must not exceed 80ft.

With regard to the dimensional tolerance that can be maintained, a number of relevant factors have to be taken into account. First, there is practically no dimensional variation from one end to the other of a given extruded bar. Secondly, since variation can only result from die wear, assuming that the original die-aperture was dimensionally correct, the closeness of the tolerance demanded is intimately related to the die costs for a particular extrusion operation. Wide tolerances, by virtue of the greater amount of wear that can be allowed, permit the die to be kept in service for a longer period so that the tooling costs are reduced. Generally speaking, it has been found that tolerance for extruded products can easily be kept smaller than for rolled products.

Interesting results have been obtained recently in connection with the production of tubes in materials that have hitherto been considered to be "un-pierceable." Several of these alloys have been extruded successfully, and tubes in heat-resisting materials are now being made available commercially. In addition to the tubular sections, solid bars of pure and alloyed molybdenum, and small quantities of zirconium, titanium, "Hastelloy B" and "Hastelloy C" as well as nodular cast iron, have been extruded with success. Shaped tubes having non-uniform wall thicknesses have been produced in France by the C.I.E.P.M. and in the U.S.A. by the Babcock and Wilcox Company. These sections are designed to provide effective heat transfer and afford extended surfaces on the inside or the outside of the tube. For the production of watch cases, a section has been extruded in stainless steel, and has then been cold-drawn to the finished form. By a similar combination of extrusion and cold-working operations, hollow gas turbine blades are now being produced from heat-resisting alloys. Tubes can be made in which the cross-section varies from end to end. The external diameter of the tube may be held to a constant size while the diameter of the bore is progressively reduced. It is also possible, by employing a special technique, to extrude tubes having a constant diameter bore and a tapering exterior. The extrusion process can, moreover, be used to produce bars and tubes that are composed of two dissimilar materials. For example, an extruded tube may have an inner surface of stainless steel, to permit the passage of corrosive liquids, and a surrounding outer layer of nickel-chrome steel to impart high mechanical strength. Recently, carbon steel rods have been extruded in which there are one or several cores of various materials. The cores are disposed parallel to the axis of the rod and are only 0·040in in diameter.

Central France

The group of delegates taking the tour of works in Central France spent Thursday, June 16th, visiting the well-known steel making and heavy fabrication shops of La Société des Forges et Ateliers du Creusot at Le Creusot and on the following day travelled to St. Chamond and Unieux to visit the several works of La Compagnie des Ateliers et Forges de la Loire. Both of these companies employ conventional open-hearth and electric steel making facilities as well as rolling mill and forging plant. We do not propose to deal with these installations here, believing that readers will be more interested in the alloy steel continuous casting installation which has been in operation at the Jacob Holtzer works of the latter firm at Unieux since 1953.

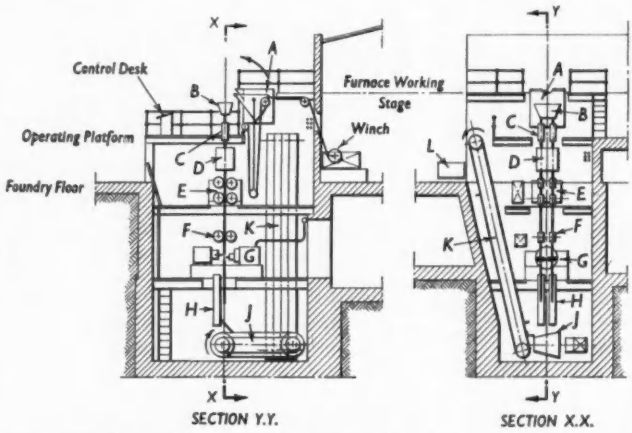

Fig. 11—Sectional diagram of continuous casting plant at the Jacob Holtzer works

The Jacob Holtzer works became interested in the problem of continuous casting of special steels during 1950, because it was felt that the process would find an important application to these grades of steel. In this respect, it was hoped that the inherently higher value of the metal and the great difficulties experienced with hot working of conventional ingots would lead to a greatly reduced cost of hot working. The price of hot working at these works on conventional ingots had been rather high, and continuous casting afforded the possibility of reducing these costs to more normal values. At the same time, it was recognised that the introduction of continuous casting would raise unfamiliar problems in works organisation. For this reason, it was considered important not to commit a large tonnage in the first place to continuous casting from the four large steel furnaces in the works, and it was decided to begin operations with the output from the small high-frequency furnaces. The first continuous casting trials were made at Unieux in June, 1950, using a very simple plant fed from a 1 cwt ladle. This small experimental plant, despite its crudity, lack of size and productivity nevertheless allowed a close study to be made of the important

factors affecting the continuous casting process.

However, it was realised eventually that all the factors involved in continuous casting could not be studied fundamentally by means of a 1 cwt installation. As soon as the possibilities of continuous casting had been established, and encouraging results had been achieved, it was decided to construct a semi-industrial plant. This began operating in August, 1951. The plant was fed with liquid steel from a 6 cwt high-frequency furnace. A cut-off device and a variable-speed roller extraction system were incorporated for the casting of oval sections 2⅜in by 3½in. This plant enabled a further study to be made of the entire process and of the refractory materials which had to be adopted in its use. It also served to study the greater part of the steel qualities made by the works and the precise conditions under which each could be cast to give steel of the best quality. This programme necessitated many hundreds of casts from which comparisons could be made with metal obtained from conventional ingots. At this stage it was found possible for the first time to produce billets having a quality at least equal and very often superior to those from conventional ingots.

The results from the continuous work on the semi-industrial plant during 1952 were estimated to be sufficiently good to justify the building of an industrial plant which was started in March, 1953. As shown in the accompanying illustration, this plant is fed from a 1½-ton high-frequency furnace, the body being used both as a melting unit and pouring ladle. The metal is poured directly from the ladle lip into a preheated tundish. The steel passes from the tundish through refractory nozzles directly into the chromium-plated copper casting moulds. It is possible to cast two strands of oval billet sections 2⅜in by 3½in or one strand of an oval section 3½in by 4½in. In the first case two nozzles are fixed at the base of the tundish directly on the axis of the two moulds, and two sets of withdrawal rollers driven from a single variable-speed motor serve to extract the billets from the mould. In the case of casting the larger section, the withdrawal rollers are centrally fixed on the drive shaft between the pair used for each nozzle in the tundish to regulate and equalise the flow of steel into the two moulds, as the billets are withdrawn at the same speed from the moulds. A suitable lubricant is applied to the moulds which are fixed, and precautions taken against undue oxidation of the steel by using a butane burner above the moulds. The casting can be set at a predetermined speed or in the course of casting operation, it is easy to change to some other speed should this be necessary. A hydraulic shear is used for cutting the billets into lengths during the casting, while a third pair of rollers situated just above the cut-off stage serves to guide the billets.

Apart from the furnace and the mould assembly the plant is situated below the foundry shop level. At the bottom of the casting bay is built a system to receive the cut billets and transport them to the floor level by means of an elevator. A control desk is situated in front of the furnace from which the tilt of the ladle and the speed of the billet extraction from the moulds is regulated. The production rate of this plant is about 1 ton per hour. The use of the high-frequency furnace, both as a melting unit and ladle, has two definite advantages. During pouring, the power input to the high-frequency coils can be regulated to maintain the liquid steel at the appropriate casting temperature. Furthermore, if difficulty is experienced in the billet casting operation, for example, due to freezing of the steel in the tundish nozzles, the ladle can be tilted back, the furnace charge readjusted and continuously cast later when the casting plant is ready again. With other continuous casting installations, in the event of a stoppage, it is usually necessary to remove the transfer ladle from the casting machine and pour the remaining hot metal either into conventional ingots or into a form suitable for remelting. The disadvantage of the Holtzer system is that during casting the high-frequency furnace cannot be used for melting another charge so that furnace time is lost.

From the accounts given of hourly throughput rates achieved by continuous casting plants in other countries, the rate of 1 ton per hour would appear to be extremely low. However, it must be said that it is governed by the special conditions at the Jacob Holtzer works, who are only concerned with high quality special steels, such as stainless, tool, high-speed and cobalt magnet steels. At the price of manipulating these difficult qualities of steels, it is advantageous, even for small tonnages, to continuously cast these grades. It has been found, for example, in a recent survey on valve steel, that where 1800 kg of ingot steel were required to produce a given length of 10mm diameter rounds, the same length was now obtained from 1300 kg of continuously cast billets. The experience obtained by the Jacob Holtzer works indicates that steels of at least equal quality and often of a quality superior to those cast by conventional methods, could be obtained by continuous casting. This is largely believed to be the outcome of acquiring long experience of the process, of very careful working methods and of scientific methods to control the process, using modern metallurgical equipment.

(*To be continued*)

Technical College Libraries

A SERVICE TO INDUSTRY

By GORDON H. WRIGHT, A.L.A.

At the recent conference on Co-operation in Engineering Research between educational institutions and industry,[1] the speakers suggested that some form of bureau was necessary to act as a clearing house for information between industry and the educational establishments. Mr. Nixon made the observation, "It was safe to assume that many industrial concerns spend much time and effort in dealing with problems which have been solved elsewhere. A piece of correct information in the right place at the right time could save considerable time and expense and possibly misdirected research." These simple statements of fact point to an apparent failure in the policy pursued by technical librarians and information officers in the dissemination of technical information. The work of the various research associations, T.I.D.U. and other Government information services would not appear to be as all-embracing as they should be.

On the other hand, during the Aslib conference before Christmas librarians and information officers were protesting that so few scientists and technologists seemed able to use information services profitably. Whilst Dr. Urquhart drew attention to the vast majority of small British industries who not only had no library of their own, but rarely attempted to seek the assistance of existing private and Government research organisations.

Undoubtedly part of the reason for this can be traced to the few libraries established in technical colleges before 1946. Whereas university students were, and are, encouraged to seek information for themselves, and have ready access to good libraries, the majority of technologists and technicians trained in technical colleges have never had the same opportunity. Certainly in this respect these colleges have always been the "poor relations of the universities," whilst the parsimony of education authorities in the provision of books and library staff is still the subject of much concern.[2]

As those trained in these establishments form the bulk of industries' trained labour force, it is a matter of some significance to realise so few have received adequate training in how to seek, collate and apply the theories of others for themselves. Students are not alone in this. Many members of the teaching staffs are equally inexperienced. In a survey at an establishment training teachers for technical colleges the students were asked to consider the use of a library in an educational establishment which produced the following remarks amongst others equally fallacious: "The library is a place where work can be done at mealtimes," and "the student has never had any experience in finding information for himself, and should never be left to do so"! Apart from the fact that these students should have had previous experience in the use of a library during their own careers, one may well ask how many technical teachers have been appointed since 1946 with no knowledge or training in how to enable their students to make the best use of library resources.

It is obvious from the foregoing and the poor book stock of many colleges that very few people appreciate the service that a well-equipped college library can render both to the college and to local industry. At a time when some attention is being given to the need to provide a technical library in many counties and provincial towns it is essential for more thought to be given this matter. Particularly when there are many who consider the college library as merely providing a simple solution to the provision of the humanities in the syllabus. In this respect, as was stated so aptly in *Nature*, "what matters is not so much the medium as the character of the training and the prestige of the humanities in this respect is not so much due to their field as such . . . as to the way in which in certain schools they have been taught."[3]

The primary function of the college library is to provide an extensive, comprehensive collection of material dealing with those subjects taught in the college, together with sufficient general material to enable the student to appreciate the background and application of his subject. In other words, the humanities as mentioned at the Eusec Conference on Engineering Education,[4] but not to the extent that the provision of technical literature suffers. Apart from the service to the student, however, it has to provide the staff—both full-time and part-time, frequently numbering well over one hundred—with the material they require for their lectures, to keep them informed of new developments

and to assist them in any research activities they may be undertaking.

In terms of stock it will be appreciated that this will mean that beside the ample provision and duplication of many advanced and expensive books other material must be provided—abstracts, standards, patents, statutes, technical trade literature, and, above all, a wide range of periodicals, both British and foreign. Retrospective files of periodicals become more important as the standard of school work advances. In many cases, when space is at a premium, there is need to provide microfilm readers and certainly some form of equipment for photographic reproduction.

Trade literature can be put to a variety of uses in a college and it is surprising that there are still some firms who fail to appreciate that in the long run they are likely to profit from this form of co-operation. Apart from the technical data photographs of equipment are useful even if they are merely used as a practical means of illustrating to students an industrial application of a particular theory. Detailed dimensioned drawings of simple standard items of equipment which many firms are very chary to hand over are excellent to use as examples in drawing classes, quite apart from the fact that they enable the students to become familiar with equipment they are likely to use in the normal course of their duties.

This is only one link that the librarian will forge with industry. Few libraries can hope or afford to become self-sufficient and the librarian seeks to co-operate and co-ordinate his stock with other librarians in his area. He endeavours to contact and co-operate with other specialised sources—the Science Library, the National Central Library, Aslib, and the various research associations active in those fields of technology of interest to the college. In fact, the librarian seeks to provide a channel for the dissemination of information between local and national organisations and his own college. Such a service is reciprocal and it is worth noting that in the provision of technical literature the well-stocked college libraries are called upon to loan far more material than they seek to borrow for their own needs. Many urgent inquiries for information are made by telephone and this service will vary with the number and value of alternative sources in the district. Thus, when the Research Association of British Rubber Manufacturers moved to Shawbury the library at the National College of Rubber Technology had a marked increase in the number of inquiries it received from outside sources.[5]

A few facts regarding established and flourishing college libraries may not be out of place. Manchester has a stock approaching 40,000 volumes and receives 450 periodicals. Apart from the continuous use made of the library by the college over 500 visits by members of the public were recorded in 1952 and 491 volumes were loaned to industry between April and December, 1952. A similar story is echoed elsewhere : Glasgow, 22,000 volumes, 360 periodicals ; Northern Polytechnic, 14,000 volumes, 215 periodicals ; Leicester, 15,000 volumes, 394 periodicals.

Even in those colleges where libraries have only recently been established their contribution to the training of the students and their direct assistance to industry can be clearly assessed, e.g. Coventry, 12,000 volumes, 206 periodicals, with 120 loans to industry. In London the L.C.C. has made steady progress and as many of their colleges specialise in training students in particular branches of industry, the libraries which have been established reflect one subject that previously may have been poorly served in the area. Thus, the library of the London School of Printing and Graphic Arts, 8000 volumes and 180 periodicals, has introduced students to technical literature, and the services rendered by PATRA, that they may never have had the encouragement to see, although St. Bride's is at hand.

The provision of any such adequate technical library and information service is an expensive proposition. Expensive not only because of its stock, but for the skilled qualified staff necessary to administer the service. It is therefore essential to ensure that the library is at a centre where maximum internal use can be made of its resources. Occasionally in the larger towns, such as London or Manchester, the demand for technical libraries is so great that more than one service must be provided, in which case the mutual co-operation of the librarians concerned ensures that unnecessary duplication does not arise. In the smaller towns and counties where one good source of technical information may suffice, the technical college is in a unique position, for it can be a meeting place for specialists rather than a clearing house—as the alternative service of the public library technical bureau. As the college draws many of its students and part-time staff from local industry, encouraging them to use the library, even when they leave the college, will help to forge a greater link than already exists, and both will prosper from the resulting interchange of ideas that the library fosters.

However, before such an integrated industrial-college-library service can operate successfully in many areas there will have to be a change in the attitude of many education authorities. Few of these authorities have attempted to adopt the various recommendations for college libraries[6] and librarians' that have been issued. Apart from this the Government could well give a lead. At the moment, at least in regard to library service, the fears expressed in *Nature*, and echoed in a letter in *The Times Education Supplement*,[9] may well be a fact—" the work of the technical colleges might well be seriously impaired if it were thought that the task of training technicians and craftsmen were less important than or inferior in stage to the task of training technologists.

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Opening of the Usk Dam in South Wales

The Usk dam, which has been built for the water supply of Swansea, is an earthen embankment 109ft in height and 1575ft long. It forms part of a scheme which will yield 8 m.g.d. The scheme includes about 33 miles of pipeline to Swansea and a treatment plant. The dam is of interest because of the use of sand drains to relieve pore water pressure in an underlying silt layer, and " blanket " drains in the filling material to relieve pore water pressure during construction.

ON Saturday last, August 6th, a ceremony took place at the Usk dam, which was opened by Her Majesty The Queen. The dam forms a reservoir at the head waters of the Usk River and is situated on the border of Brecknock and Carmarthen, about 3½ miles up the river from Trecastle. It has been built for the Swansea Corporation and is the major element in a water supply scheme which will yield about 8 m.g.d. A substantial contribution to the cost of the dam has been made by the Welsh Board of Health under the provisions of the Distribution of Industry Act, 1945.

The dam is an earthen embankment, with a maximum height of 109ft and a length of 1575ft. It forms a reservoir with a storage capacity of 2700 m.g., in which water is collected from a direct catchment 3300 acres in extent, and a further 550 acres of an adjoining catchment through an intake on the Nant Henwen. The source of supply is a new one for Swansea, water having been taken from the Cray and the Upper and Lower Lliw rivers up to the present ; the new supply will end a period of shortage.

Water impounded in the Usk reservoir passes to supply through a tunnel under Mynydd Myddfai, leading to an outlet basin. From the outlet basin a 28in diameter pipe carries the water 10 miles to the treatment works at Bryn Gwyn, some 2 miles south-east of Llandilo. After filtration and sterilisation the water passes into a clear water storage tank and thence into a 27in pipe for a further 9 miles to a break pressure tank at Graig Fawr, south of Ammanford. From this tank the pipeline is 26in in diameter as far as Penllergaer, where it divides into two 20in pipes leading to service reservoirs at Cockett and Clase. Provision is made throughout for the duplication of the pipeline and increasing the number of filters when the necessity arises.

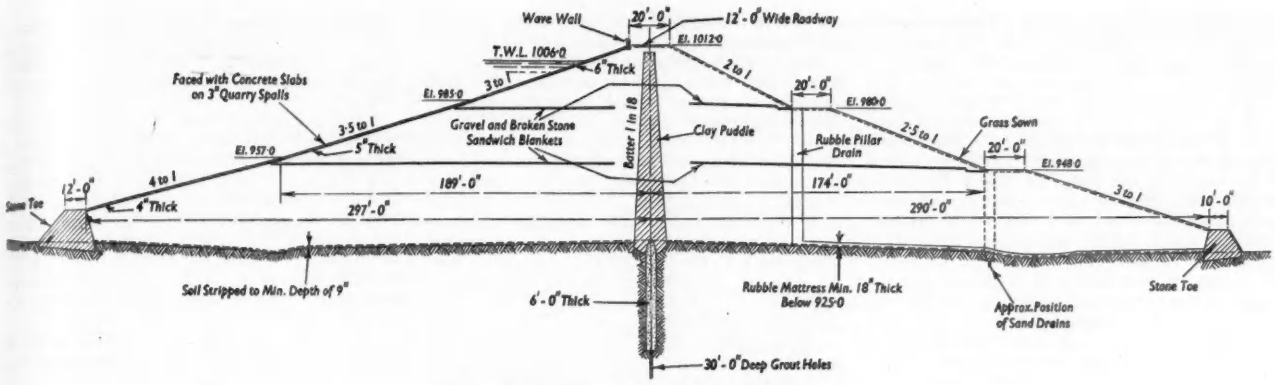
The catchment area, consisting of moorland and high mountain pasture, rises to 1800ft above sea level. The average annual rainfall varies from 85in on the highest area down to 55in at the dam, the average being 60in. When the reservoir is full it extends over 290 acres, stretching for a distance of about 2¼ miles upstream from the dam. The yield of the scheme is 8 m.g.d. for supply to Swansea and 2 m.g.d., measured at a weir downstream from the dam, flow down the River Usk as compensation water.

Design of Usk Dam

The dam is shown in the accompanying illustrations, the cross section showing its general construction. It has a clay puddle core-wall 6ft wide at the top, increasing to 16ft at the deepest part, with a concrete cut-off below it extending down to rock. Grouting was carried out below the cut-off wall, as indicated on the drawing.

Beneath the dam is a concrete-lined tunnel of horseshoe section 366 yards long, used during construction to divert the River Usk and designed to take its full flow. In the tunnel there are two lines of 18in diameter scour pipes through which the reservoir can be emptied if necessary. At the upstream end of this tunnel there is a concrete bulkhead 8ft thick, and both at this point and around the tunnel lining a considerable quantity of grout was injected into the ground. Compensation water is passed through these pipes.

It was originally intended to use the reservoir head for operating a water-turbine-driven generator to supply local lighting and power on the permanent works, but this proposal was abandoned as a supply from the grid became available. The scour pipes have therefore been constructed to discharge through valves and jet dispersers into a stilling basin where the energy of the water is absorbed.



Typical cross section of the Usk embankment

At the south end of the dam there is an overflow weir, discharging to a spillway channel 40ft wide, and stilling pool ; these elements are shown in the illustrations. The spillway channel follows the natural slope of the ground rather closely and is steeply sloped at about 1 in 4. Baffle piers have been constructed in the channel with the object of inducing turbulence in the spillway discharge, and hence reducing its velocity of flow. The draw-off tower forms a separate structure to the north of the dam.

Sand Drains and "Sandwich" Blankets

From an engineering point of view the dam is of particular interest because of the use of sand drains in its construction to relieve pore water pressure in a layer of silt beneath it. A description of the problem presented by this silt layer and the way it was overcome has been given by Messrs. Sheppard and Little in a paper entitled "Stabilising an Earth Dam Foundations by Means of Sand Drains," presented at the Fifth Congress on Large Dams in Paris last June. The following five paragraphs are abstracted from that paper.

"The whole of the area is underlain by the old red sandstone formation of Devonian age. This formation is entirely covered in the dam area by a mantle of drift with a maximum thickness of 60ft. This drift, known as boulder clay, is the result of the Quaternary Ice Age and is an entirely unsorted heterogeneous mixture of clay containing boulders and small fragments derived from both the local and more distant rocks. At times the glacial conditions may have been less severe and more closely sized fine-grained deposits associated with lakes would then be formed. The geological surveys and reports on the reservoir area did not refer to the possible existence of lacustrine deposits, and the subsequent discovery of an extensive silt bed under the seat of the embankment necessitated close investigation and the special measures now described.

"The shear strength of a soil may be expressed approximately by the empirical equation :—

$$s = c + (\sigma - u) tg\phi \quad \ldots (1)$$

s, shear strength.
c, unit cohesion.
σ, total pressure acting normal to the incipient slip surface.
u, pore water pressure.
ϕ, angle of shearing resistance.

The difference $(\sigma - u)$ is termed the "effective" pressure because it controls the frictional part of the shear strength. Thus, for large pore water pressures the shear strength tends to be reduced to c the cohesion, which is rather small for silts.

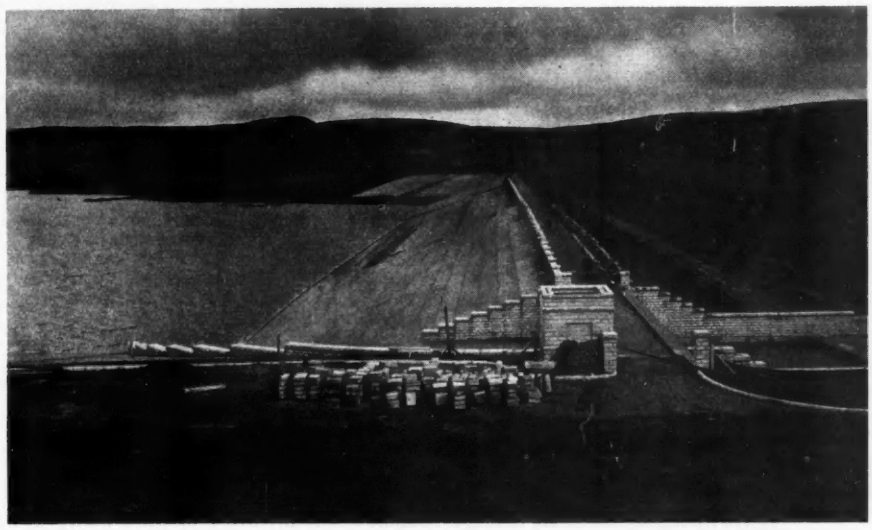
"As the load of the embankment is placed on the ground, pressures are set up in the pore water of the silt below and between individual soil grains. It is with intermediate soil types like silt that the greatest trouble is experienced because their cohesive strength is not high and their rate of gain in strength from the superimposed load is slow. With the passage of time water drains away through the materials to the free surface and the pore water pressure is relieved, automatically causing an increase in the frictional part of the shear strength. There will also be an increase in the cohesion, but this is much less important for silt than for clay. A rough calculation showed that if the silt had been free draining, 50 per cent of the excess pore water pressure would have been dissipated in about eight months, which would have permitted the necessary increase in shear strength to have kept pace with the bank building.

"Unfortunately, the silt layer was embedded between layers of clay which had permeabilities of only about one-tenth that of the silt. In these circumstances, it would have required about seven years to dissipate 50 per cent of the pore water pressure and a very long time indeed for complete dissipation. Thus there was the prospect of considerable pore water pressures building up during construction of the dam with the likelihood of a foundation failure. The possibility of removing the silt entirely and replacing it with a suitable fill was considered. It was estimated that including the necessary stripping of overburden and replacement with compacted fill, this operation would have cost at least £25,000.

"As an alternative, the use of sand drains was considered. A trench 300ft long was dug having a bottom width of about 3ft with a single row of 8in diameter borings at 10ft centres put down from the bottom of the trench into the silt bed. The borings, which were made with hand rigs, were backfilled with fine to medium sand and a 12in layer of sand was placed in the bottom of the trench. This sand layer was connected to a rubble drainage mattress which was placed under the outer part of the downstream slope. The total cost of installing the sand drains was £3360 and the investigation by borings cost £1400."

The position of the sand drains, with the trench above them crossing the dam transversely 175ft downstream from the core, is indicated approximately in the cross section. The silt layer extends under a large part of the central area of the dam, and has a maximum thickness of 8ft in this area. It outcropped at the natural ground level in one small area on the upstream side of the dam, and a horizontal sand drain was built there connecting with the stone toe.

The pillar drains and downstream drainage mattress at formation level may be seen on the cross section. These drains are normally provided on earth dams. But special measures were needed to guard against pore pressures building up in the newly placed filling as the dam was constructed. The cross section also shows the "sandwich" blankets which were built to assist in the dissipation of these pore pressures. It is well known that during construction with certain clays high pore water pressures may build up as the filling material is placed and consolidated. These pressures take some time to dissipate and may control the rate at which an embankment may be built. In this case the drainage provided by the "sandwich" blankets accelerated the pressure dissipation and so the work could go ahead at a greater rate without endangering the stability of the bank. The "sandwich" blankets consist of a layer of broken stone between layers of gravel.



The Usk dam. The wave wall and upstream face of the embankment, which is covered with concrete slabs, are shown. The overflow weir and recorder house are in the immediate foreground, with the wave wall at the north end of the dam also shown

Pore water pressures in the silt and in the dam itself have been measured and recorded throughout the construction, and measurements are still being made. The Building Research Station of the D.S.I.R. has been carrying out this aspect of the work.

Construction of the Dam

The embankment has a maximum width of 640ft at the base and contains 824,000 cubic yards of filling and 36,000 cubic yards of puddle clay, both of which were obtained from within

the reservoir area. As a public highway existed across the area flooded by the reservoir new roads had to be constructed on both sides of the reservoir.

The concrete cut-off trench is about 1550ft long, 6ft wide, and it has a maximum depth of 77ft. It runs along the centre line of the dam, up a steep slope at each end, culminating in a gradient of 1 in 8 on the south side of the valley. Orthodox timbering for deep cut-off trenches was adopted, with horizontal sheeting of 9in by 3in section, soldiers of 12in by 6in and struts of the same section, set at 6ft 6in centres horizontally and 4ft 6in centres vertically in each case.

Due to the necessity of economising in timber, which was in short supply in 1950, the contractor was allowed to construct the trench in three equal sections. Excavation from the trench was handled by 5-ton steam travelling cranes on earth banks on the flatter part of the valley, but 5-ton derricks were used on the steeper slopes at the sides. Compressed air for pneumatic tools was supplied by a stationary compressor with a free air delivery of 1000 cubic feet per minute driven by an electric motor of 130 h.p.; this equipment worked throughout without a single breakdown.

The nature of the ground in which the cut-off trench had to be excavated presented the usual difficulties associated with the fluvio-glacial deposits which contain lenses of silt. The question of using steel sheet piling was discussed in the early stages of construction, but owing to the shortage of steel and the presence of boulders it was decided to support the trench with timber. Later, when timber became difficult to obtain, steel sheet piling was used. In spite of the difficulty of driving such piling through bouldery ground, the method was fully justified, we are informed, by the marked increase in rate of excavation. Drilling of grout holes to a depth of about 30ft was undertaken in 10ft and 20ft stages, using drifter drills on columns, with bits of tungsten carbide. Grouting was done with a modified steam pump driven by compressed air, fed from a mixing tank agitated by electrically driven paddles ; it was found to be a successful unit.

Concrete was mixed at a central plant, but heavy gradients precluded the use of a Jubilee track and skips. Petrol-driven dumpers of 2 cubic yards capacity were adapted on site to carry concrete skips. When timbering was stripped, in some cases silt flowed out, causing cavities which had to be filled with concrete. A total of 13,000 cubic yards of concrete, terminating in a " spear head " forming a watertight junction with the clay core, was needed in the cut-off trench.

The main body of the dam with its puddle clay core wall was constructed over a period of four years. Work on embankment fill had necessarily to be suspended at this exposed site in the Welsh mountains during the winter months when weather bogged down the modern earth-moving plant which is nowadays in general use. The contractor worked a night shift during the Summer and assembled a high concentration of plant to maintain progress. The filling material was spread by bull-dozers in 1ft layers and was mainly compacted by the earth moving plant passing over it, and by a tractor-drawn pneumatic " wobbly-wheel " roller. Absorption of rain was reduced by making the surface as smooth as possible and by maintaining a fall from the puddle wall to the edge of the filling.

Aqueduct and Water Treatment Plant

The outlet tower, at the commencement of the supply tunnel, provides for the water to be drawn off at depths of 16ft, 36ft and 64ft below overflow level (1006ft A.O.D.)—each intake being controlled by an external sluice and internal valve all operated by headstocks in the valve house, which is reached by a footbridge from the road on the north side of the reservoir. At the outlet end of the tunnel there is a supply basin, the flow into which is controlled by float operated valves. The basin is divided into halves, one of which is connected to the pipeline already laid, the other being for use with the future pipeline. The tunnel is lined with concrete and is designed to withstand the full hydrostatic head of the reservoir. Its original cross section was enlarged to enable mechanical plant to be used to full advantage.

The water treatment works are sited at Bryn Gwyn near Llandilo, and they have been designed to treat 8 m.g.d. with provision for extension to treat double that quantity in the future. Water enters from the supply basin through a 28in diameter steel pipeline and flows through inlet chambers, where sulphate of alumina is added as a coagulant and soda is also added to regulate the hydrogen ion concentration. The water then passes to mixing chambers and reaction tanks where it remains for half an hour before passing through the rapid gravity sand filters, all equipped with hydraulically operated controls.

There are eight rapid filters, each 30ft by 20ft in plan. After filtration, the water is further treated with chlorine and lime ; after the filtered and treated water has been held in the filtered water tank for 20 minutes, it is passed into the 27in diameter steel main of the aqueduct. The filtered water tank is of semi-underground construction and has a capacity of 460,000 gallons, Steel shuttering of novel design was used for these works, and all the concrete was distributed by monorail. The power and lighting requirements of the plant are provided by three diesel driven generating sets each with an output of 16kW at 230/300V.

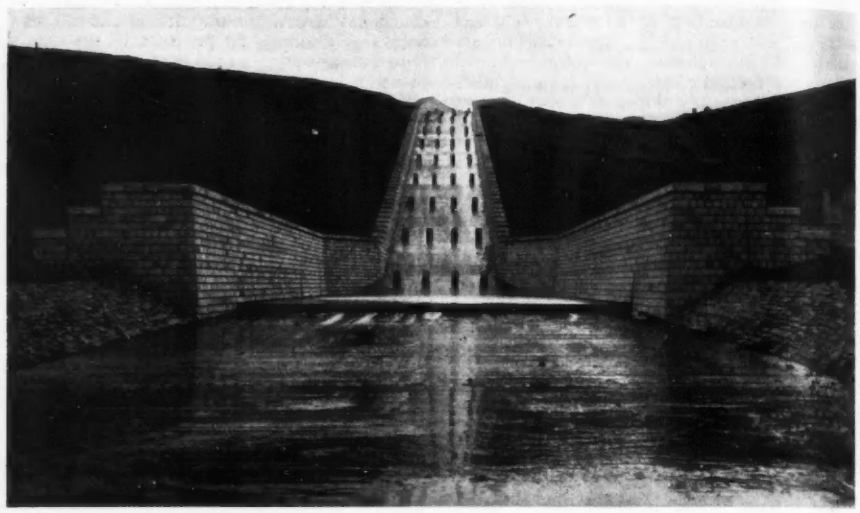
Steel pipes, lined and sheathed with bitumen, with flexible couplings have been used for the pipeline. The thickness of the steel is varied to suit the changes of pressure occurring along the line, the maximum being 750ft head at the Afan Sawdde one of the valley crossings. The flexible joints permit some movement of the pipes, if ground settlements should occur, without leakage. Tne line can be closed at points about 1½ miles apart by sluice valves, at some of which provision is made for cross connections with the future line. Scour branches are fitted at all low points on the line and access manholes with air release valves are provided at all crests.

In order to limit the static pressure which would develop in the pipes if the terminal valves at Swansea were closed the line is divided into three roughly equal lengths, the pressures being limited to that due to the small reservoirs at the supply basin, filtration plant and break pressure tank. At each of these points the outlet valves are arranged to close automatically should a fracture in the pipeline downstream cause an increase in the rate of flow.

The diameters of the pipes are varied to suit the gradient available in each section. The first section is 28in diameter and about 10 miles long ; the second from the filters to the break pressure tank, is 27in diameter and 9½ miles long and the third is 26in for the first 7 miles to where it divides into two 20in pipes, each about 3½ miles long, which feed into the service reservoirs at Cockett in the west and Clase in the north of Swansea. A number of river crossings, where the pipes are supported on concrete piers, had to be provided—the piers being wide enough to support the future line also.

The pipeline passes across rugged country and excavation had to be carried out in a variety of ground conditions from solid rock to boggy peat. The method of working was adapted to ground conditions, but generally it was possible to use crawler mounted excavators for the digging and bulldozers for restoration of the land. At the steep-sided valleys light railway track was laid for distribution of pipes and concrete by power winches and diesel locomotives.

The consulting engineers responsible for the design and supervision of the Usk scheme were Messrs. Binnie, Deacon and Gourley. The civil engineering contractor for the dam, pipeline and treatment plant was Richard Costain, Ltd. The Swansea borough water engineer and manager, Mr. T. Price, was responsible for the terminal reservoirs at the Swansea end of the scheme. Other contractors were : treatment works equipment, the Permutit Co., Ltd.; supply of steel pipes, Stewarts and Lloyds, Ltd.; treatment works power plant, R. A. Lister and Co., Ltd. The cost of the scheme was £3,108,000 made up as follows: reservoir works, £1,319,000; pipeline, £1,212,000 ; treatment works and break pressure tanks, £436,000 ; terminal reservoirs (Cockett and Clase No. 2), £141,000.



The spillway of the dam and the stilling pool. The baffle piers in the spillway channel induce turbulence and hence reduce the velocity of flow of the spillway discharge

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Asphalt Road Surfacing on Concrete Bases.—The Asphalt Roads Association, in conjunction with the Cement and Concrete Association, recently carried out an investigation to determine the most suitable design for road construction when employing asphalt surfacing on a concrete base. The results of these investigations show, it is stated, that a continuously reinforced concrete slab without expansion or contraction joints is more suitable as a concrete base for hot rolled asphalt for the following reasons ; the presence of reinforcement, and the absence of joints in the slab, ensure that there is no relative vertical movement between adjacent points which might cause the surfacing to crack ; if the reinforced concrete base develops cracks, they are small and are unlikely to be reproduced in the surfacing; continuously reinforced concrete is an economical form of construction, as it allows a minimum thickness of concrete to be laid, and delays due to joint construction are eliminated. It is recommended that the design and construction of a concrete base for asphalt surfacing should follow normal reinforced concrete road technique. Construction joints should have the reinforcement carried through and on a poor soil it may be advisable to include tie bars or extra reinforcement as additional insurance against opening and relative vertical movement. Tie bars should always be provided in longitudinal joints. The greater the thickness of the asphalt surfacing, the better will be the performance of the base. The possibility that the omission of expansion joints might lead to a compression failure in the concrete base during hot weather was considered, but if the recommendations given are adopted, the risk is so small that it can be disregarded, it is stated. Satisfactory results have been obtained with asphalt surfacing 1½in thick but surfacing not less than 2in in thickness is recommended.

Practical Experiences with the JEEP Reactor*

By T. J. BARENDREGT, N. HIDLE, A. LUNDBY, E. SÆLAND and G. TRUMPY†

The construction of the reactor installation, JEEP, at the Dutch-Norwegian Joint Establishment for Nuclear Energy Research (J.E.N.E.R.), was started in 1948, *at Kjeller, near Lillestrøm, Norway. The reactor became critical in the last days of July,* 1951, *and has been in operation almost continuously since then. The main activity at Kjeller is related to the use of the reactor as a research tool and as an isotope producer. Many physicists and engineers from abroad have performed their own experiments with the reactor or have taken part in experiments with the establishment's staff.*

THE research reactor known as JEEP is a natural uranium heavy-water-moderated and cooled reactor. The designed power level was 100kW, but the actual level has gradually been increased to a maximum of 350kW, with a corresponding central thermal neutron flux of approximately 10^{12}/cm² sec. The moderator water which is kept well below 100 deg. Cent., removes the generated heat from the fuel elements by natural convection. Heavy water is removed from the top of the reactor and circulated to an external heat exchanger, where it is cooled by ordinary water before returning to the bottom of the tank. A closed circuit is chosen for the ordinary water and this is cooled in a water-to-air heat exchanger. The heat energy is finally discharged to the atmosphere ; part, however, is used for heating the reactor building during the winter.

The reactor tank, 2m in diameter, is surrounded by a graphite reflector 0·7m thick. Cadmium plates, two for control and two for shut-off, are placed between the tank wall and the reflector. The plates, 35cm by 130cm, can be lowered into slots in the concrete floor below the reactor. A manually-operated shim rod is placed in one of the six channels penetrating diametrically through the tank. Biological shield is ordinary concrete lined with cadmium on inner walls, the minimum concrete thickness being 2m.

In addition to the above-mentioned six channels, which pass through from one side of the concrete block to the opposite side, there is a thermal column and two channels extend through the graphite reflector on to the tank wall. This is a low number of openings for a research reactor of this kind. To ease the situation, both horizontal channels which normally contain neutron detectors and vacant fuel element holes in the top of the tank are used for experimental set-ups.

The fuel is metallic uranium, canned in aluminium. The fuel elements, spaced on a square lattice of 18cm centre to centre distance, consist of two uranium rods each 1in in diameter. The rods consist of six and a half individual uranium bars 11¼in long. At present, the reactor is operated with sixty-five fuel elements, the maximum number being, however, seventy-six. The sixty-five elements have a total weight close to 2·3 tons. The total heavy water content in the system is 7 tons.

It might be of interest to note that the entire installation is built from conventional and non-restricted materials and components. Aluminium used in rod construction, tank and tubings, is of an ordinary technically pure quality (2S). Steel used in pumps, valves, heat exchanger and tubings is of commercial quality with C, Cr, Ni and Mo content 0·05, 18, 9 and 1·5 per cent, respectively. All connections of stainless steel to aluminium in the circuit are electrically insulated to prevent corrosion. Gasket material is largely "Neoprene" through the entire system.

Six separate neutron sensitive systems are located in the reactor. One is used for the main reference of power level. Three are used as shut-off channels, these will actuate the shut-off plates if the power should exceed a pre-set level. One is used for automatic control of power level. The last one is battery-driven and current from the detector passes directly to a galvanometer. This sixth system is installed to be able to see that the reactor shuts off in cases when the main current supply falls out. All neutron detectors are "T.P.A." ionisation chambers with BF_3 filling.

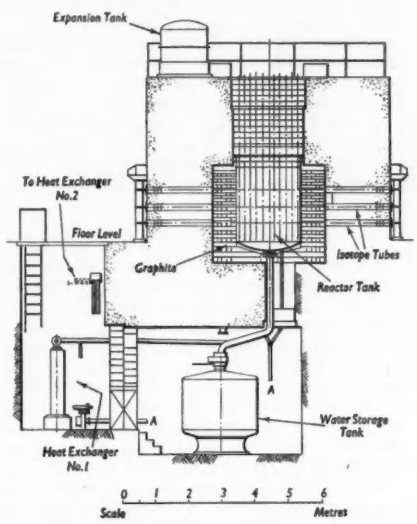
* Abstract. Paper presented at the International Conference on the Peaceful Uses of Atomic Energy. Geneva, August 8–20, 1955.

† All the authors are with the Joint Establishment for Nuclear Energy Research, Kjeller, near Lillestrøm.

First Start-Up of Reactor

The exact amount of uranium and heavy water needed to get the reactor critical was not known in advance. The first starting-up, therefore, had to be done very carefully. All seventy-six fuel elements were mounted in position in the reactor, a 100mC, Ra-Be source was placed close under the bottom of the reactor and heavy water was pumped in portions into the tank. BF_3 counters placed inside the reactor core gave counting rates which were plotted inversely against the height of heavy water. By extrapolation a very good value for the critical water level was obtained. The Ra-Be source was removed during the procedure when the multiplication factor was large enough to multiply the background neutrons to such an extent that they could be counted with the BF_3 counters. All cadmium plates were drawn out of the system during the start-up.

The critical water level in the tank was so low at the initial start-up that water did not reach up to the outlet tube for circulation. Fourteen fuel elements were therefore removed from the tank



Diagrammatic sketch of JEEP reactor at Kjeller, Norway

so that circulation level could be reached without the system having too much excess reactivity. Later, three elements were reinserted to compensate for isotope loading.

To-day the start-up is an easy routine procedure. The neutron sensitive instruments, which are calibrated in kilowatts of power level, are switched to a sensitivity range where the background of neutrons can be detected. First, the two shut-off plates are withdrawn one at a time. Then the two control-plates are carefully taken out, also one at a time. Normally the reactor is still sub-critical after these operations, due to the rather large shim rod in the lowest horizontal channel. The shim rod is then gradually withdrawn until criticality is reached. The pile period is watched very carefully during the entire procedure. The shim rod is withdrawn so far that the doubling time of the reactor is approximately thirty seconds. The power level is then allowed to increase until the desired operating level is reached. Control cadmium is then inserted manually to stabilise the level. The automatic control circuit can then be put into operation.

When the moderator is heated up, cadmium has to be taken out to compensate for the negative temperature coefficient. This is done with control plates in the first instance, and the shim cadmium is withdrawn step by step to keep the control plate in a practical working range. When shutting down the reactor, even for short intervals, all the cadmium is reinserted and starting-up has to proceed from the beginning. This rule is established to prevent the operators misjudging load changes.

Reactor Operating Experiences

Since JEEP is our first installation of this kind, we are naturally very interested in gaining experiences with operation and maintenance of the reactor. To be able to follow the behaviour of the more important parts and equipment, we inspect fuel elements, reactor tank wall, pumps, valves and other accessible parts regularly.

Inspection of fuel elements is carried out in a simple and, in our opinion, effective way. The highly active fuel elements, accumulated dose up to 110Mwd per ton uranium, are hoisted from the reactor into a lead coffin placed on top of the reactor shielding. This coffin is used for transporting burned fuel to the "cooling-down well," but for inspection it is placed with the rod inside on top of a lead cylinder with an epidiascope built in. The fuel rod is then lowered from the coffin into the cylinder, passing the epidiascope on its way. An enlarged picture of the element can then be projected on to a screen. Turning the element and focusing the optical system can be done from a distance, i.e. by the inspector sitting in front of the screen. With this system, very small irregularities and also colouring effects on the canning can be discovered.

Although fuel elements in JEEP were made without knowing much about how to "can" uranium, very little trouble has arisen up to now. Five rods have been removed due to corrosion of canning material or "blister formation," but with to-day's knowledge, we probably would not have removed more than two of them. The corrosion attack on the canning which was serious enough to cause removal of elements, was due to copper particles pressed into the canning surface, giving local galvanic elements. Some general corrosion attack has been observed on non-treated canning surfaces. Fuel elements which have been anodically oxidised have shown remarkably little or no attack at all. New elements are now treated in this way. Blister formation is probably due to moisture inside the canning reacting with uranium and resulting in uranium oxides or uranium hydrides in local spots. The result is an increased volume which can cause very sharp warts in the aluminium tubing. Several of these blisters have been formed, the largest has been up to approximately 3mm high and 15mm in diameter in the bottom. No burst of canning has occurred. All fuel elements are inspected twice a year, and, according to the records, it seems as though most blisters stabilise on a reasonably small size, less than 1mm high. Since blisters have also been found on fuel elements which have been stored, it is concluded that the effect is not primarily dependent on conditions in the reactor.

The inner wall of the reactor tank is inspected by means of a periscope. Fuel elements on the tank circumference are raised to make room for the periscope. No serious defects have been found in the welded tank structure. The walls are, however, tarnished with a grey aluminium oxide layer.

Since the initial start-up, the reactor has been checked for corrosion seven times. The corrosion effects in the reactor seem mainly to be a problem of heavy water contamination. Inspection of the valves, pumps and heat exchanger of the heavy water system revealed corrosion attacks on the stainless steel material, which have resulted in the introduction of rust particles into the heavy water system.

Since the conductivity of the heavy water will give an indication of the dissolved impurities, the conductivity is measured regularly. A twentyfold increase of the conductivity of the heavy water by the end of 1954 indicated contamination by corrosion products.

As a comparison, the pD was determined. Doubly-distilled heavy water with a so-called "apparent pH" of 6·2 was used as a standard. The apparent pH of the heavy water in the reactor system appeared to be slightly decreased to 4·8–5·0, which also indicates dissolved products in the heavy water. With diphenylbenzidine as a reagent, nitrate ions could be

detected and a quantitative determination showed an amount of 10mg per litre present. It is obvious that only a small percentage of this nitrate in the heavy water as free nitric acid would cause the lower pH. The elements listed in Table I were determined spectrographically in the residues obtained after distilling off the heavy water.

Due to the decomposition of the heavy water, D_2O_2 is present. During operation of the reactor, an average value of 10mg D_2O_2 per litre was obtained, but this amount decreases when the reactor is shut down for a longer period.

TABLE I—*Data of the Heavy Water in the JEEP System (January, 1954).*

1.	Composition	99·8–99·85 per cent D_2O
2.	Conductivity	$17 \cdot 10^{-6} \Omega^{-1} cm^{-1}$ at 25 deg.Cent.
3.	pD (apparent pH) ...	4·8–5·0
4.	Nitrate	10mg/litre
5.	D_2O_2	18mg/litre
6.	Residue	50mg/litre

Components of residue :

Al 9 ppm D_2O	Cr 0·1 ppm D_2O
Ca 0·05	Ni 0·15 ppm D_2O
Cu 0·15	B 0·05 ppm D_2O
Pb 0·9	Si 1·1 ppm D_2O
Fe 3·5	

On top of the reactor tank there is a layer of 1 cubic metre of air, which is circulated over a catalyst to recombine the D_2–O_2 mixture, formed in the heavy water by irradiation. The content of D_2 in the air has been measured regularly. The amount increases continuously and the air is circulated to such an extent that the D_2 content is kept at about 0·5 per cent. The amount of recombined water is a linear function of the kilowatt-hours at which the reactor is run. At a level of 250kW the amount of recombined water is now 40 ml per hour.

Owing to the impurities present, the heavy water in the reactor system appeared to be radioactive. There is a close correlation between the specific activity of the heavy water in mC/ml and the level of the reactor. To obtain some idea of the elements which are responsible for the activity, Cu++, Fe+++, Ca++, K+ and Na+ were added as carriers. From the analysis of the components it was found that approximately 70 per cent of the total activity was due to components of less than four-hour half-lives, and 2·4 per cent to components with twenty-four-hour half-lives. The contribution of more long-living components is of the order 1 to 2 per cent.

Although no precautions have been taken, no indications of serious corrosion attacks on the system have been observed. To reduce the decomposition rate at high power levels, however, plans have been made for building in a purification unit for the heavy water.

The heavy water circuit outside the main reactor shield is accessible when the reactor is shut down. Valves, pumps, flange connections, &c., in this system can then be checked quite often. In addition to the direct visual control, a leak detection system is installed. The detector, which only needs a drop of water to set off an alarm, consists of two steel plates with a hygroscopic paper between. The paper is prepared with NaCl to act as a conductor when it becomes wet. The detector is coupled in series with a battery and an alarm relay. Detectors of this kind are placed all around the installation where leakages are likely to occur. The system has often proved to be very useful.

The circulation pump in the heavy water circuit is a normal centrifugal pump. The difficult problem when looking for a pump for expensive fluids like heavy water is the shaft sealing. The sealing has to be tight, no lubrication is allowed, material choice is restricted, and low maintenance is required. In our case a standard rotating shaft seal is applied. The rotating seal itself is achieved with a ground carbon ring against a ground stainless steel ring. The system has proved to be good for our working conditions. During the four years of almost continuous operation, the shaft seal has been renewed only once. The reason for breakdown was that an aluminium particle which had managed to enter between the carbon steel ring had scratched the carbon ring so that water was able to leak out.

All valves used in heavy water lines are of a commercial available plug cock form. The valves are grease lubricated, the grease being of special quality non-soluble in water. The choice of these valves is not entirely to our satisfaction. Grease is loosened by the streaming water and is transported around in the system until it sticks to the wall somewhere. It does not cause much harm, but some trouble has arisen with the valves in a small diaphragm pump. We now believe that with the proper choice of material, diaphragm valves might prove to be better than the type used.

Gasket material used is mainly " Neoprene," either as sheeted material or as standard O-rings. The material withstands fairly well the actual conditions outside the radiation field. O-rings are also used for tightening of fuel element holes. The rings are fitted in a slot under the top flange of the fuel element construction. The gasket should seal the hole by means of the elements' own weight. The " Neoprene " however, becomes damaged rather soon in the radiation field, it hardens, turns brittle and loses its sealing effect.

Apart from the ordinary breakdown of electronic components, very few failures have occurred in the control installation. A water level indicator for the reactor tank was working on the principle of a float adjusting an iron core inside a solenoid, the solenoid being one branch of an inductive bridge. This indicator, however, did not function properly after about one year's operation. The float mounted on top of the tank under the top shielding is no longer accessible. We believe that the reason for not functioning is a broken " lucite " tube located inside the solenoid. This tube has probably caused the iron core to remain in a fixed position.

The wiring for one of two resistance thermometers recording reflector temperature is short circuited somewhere inside the radiation shield.

Resistance thermometers are used throughout the entire installation. Thermometers situated in the reactor tank can be shown to be influenced by radiation. The effect is dependent on radiation intensity ; no permanent change has been recorded.

Exposure to Radiation

Members of the staff most exposed to radiation are the reactor operating personnel. Normally, the record over a three-month period shows that the highest doses are approximately one-third of the accepted tolerance dose, which corresponds to 300 mr per week. Personnel working constantly in the radiation field use pen-type gamma and neutron dosimeters and also film badges, whilst personnel working occasionally with radioactive materials wear only film badges. Blood checks of all personnel are made regularly.

One serious case of heavy contamination has occurred. About 3kg of uranium canned in aluminium had been inserted in an irradiation channel for three weeks, after which the experiment for which it was intended was completed. It had been checked after two weeks and found in good order, but when the uranium was to be removed from the channel, the canning had burst. Due to a rather high temperature in the uranium it had oxidised strongly in the air, and quite a large amount was sprayed around, in the form of dust, when the channel was opened. All personnel were immediately evacuated from the building, and before men in protective clothing and masks were allowed to re-enter the building air samples were taken. Primarily the burst slug had to be removed. It was transferred to a container by means of long tongues, where it was soaked in oil to prevent more dust from escaping. Vacuum cleaners were then used for removing the major part of active dust, which was located in the channel, and on the floor in front of the channel. The vacuum cleaners were so highly active that they were disposed of in concrete drums. The cleaning job was then commenced with brushes and water, the washing being continued day and night over the entire building for four consecutive days. Most of the activity was then removed, but some was left in cracks in the concrete floor; after monitoring, however, it was decided that the remaining activity was not dangerous. Liquid floor polish was then used for binding the dust in the cracks, the waxing of the floor being repeated several times.

Reactor Physics

One usually attempts to make most experiments with reactors as such immediately after starting them up (breaking-in period). As techniques and experience develop, however, previous experiments are revised and new ones added. A number of physical experiments depend, furthermore, on the operation of the reactor as a whole. This is, for example, the case with reactor oscillator and danger coefficient experiments. Since they frequently have to be carried out at relatively low reactor power levels, one has to balance the available operating time between isotope production and measurements with high neutron fluxes, on the one hand, and low flux experiments on the other.

In heavy-water-moderated reactors complications arise under these conditions, due to (*a*) the presence of long-lived photoneutrons ; (*b*) the large nuclear temperature coefficient of heavy water, and (*c*) the Xenon poisoning effect.

The reactor oscillator used in connection with JEEP is pneumatically operated. The arrangement is easily moved in and out of any of the irradiation channels which run through the reactor. The effect of a sample on the reactivity is detected by integrating the first Fourier component of the signal from a boron-coated ionisation chamber placed near the reactor core. For practical and security reasons the reactor power level is reduced from a few hundred kilowatts to a few kilowatts when operating the oscillator. The background of long-lived photoneutrons will in this case tend to influence the reactor transfer function in such a way as to make reactor oscillator experiments ambiguous. In order to be able to perform such experiments at power levels of 1kW or less, it is necessary to wait several days after the power level is reduced.

The nuclear temperature coefficient of the heavy water in JEEP is about -2×10^{-4} per deg. Cent. When the reactor has been running at full power level with a maximum cooling rate, the temperature of the heavy water is 20–30 deg. Cent. above the temperature of the surrounding air. The loss of reactivity in heating up (about 0·5 per cent) cannot be tolerated in some experiments, e.g. when resonance integrals are measured with the reactor oscillator. Tne power level and temperature have therefore to be reduced. Since it is hard to stabilise the temperature of the heavy water, one gets difficulties due to spurious changes in reactivity.

As compared with other natural uranium heavy-water reactors, JEEP has an unusually low ratio of uranium to heavy water. This reflects itself in the very long lifetime of neutrons in the reactor (nearly 2×10^{-3} seconds). As a result, the stable period of the reactor is comparatively large (of the order of 1 second) even for several per cents excess reactivities. Together with the large nuclear temperature coefficient of the heavy water, this makes the reactor relatively safe. At an operating level of 250kW (maximum thermal neutron flux $7 \cdot 54 cm^{-2} sec.^{-1}$) the Xenon poisoning suppresses a reactivity of 2×10^{-5} after running the reactor for a few days. The build-up after reactor shut-down is negligible.

The reactor power level will be increased by at least a factor of two in the near future and the Xenon effect will increase correspondingly.

Neutron Physics Research.—The JEEP has shown itself to be a very good tool for experiments in neutron physics, the only disadvantage being a shortage of experimental channels. For physical research the two " fast neutron channels " leading to the reactor tank wall, and two of the six " isotope channels " going all the way through the reactor are available. Further, there is the thermal column, but so far this has only occasionally been used for physical research. [Some of these research activities were referred to in the paper.]

Isotope Production and Research

When the plans for the Kjeller reactor and its connected laboratories were drawn up, some provisional facilities for the preparation of radioactive isotopes were also included.

As mentioned earlier, the JEEP became critical in July, 1951. This did not mean, however, the immediate possibility of an effective isotope production. Because of desirable changes in the top shielding the reactor was shut down for about half a year after it had first started. Then followed the running-in period, during

which routine production of radio-isotopes was impossible.

From January, 1953, there has been a normal reactor operation and more than 1000 isotope shipments have since then been dispatched from Kjeller to customers outside the institute. The rate of isotope shipments has been doubling every year. An important part of the shipments consisted of irradiated, non-processed material which was separated and distributed both in Europe and overseas by the pharmaceutical firm N.V. Philips-Roxane, Amsterdam. The direct shipments from Kjeller were mostly for the Scandinavian countries. Most current "carrier free" pile isotopes are being or will shortly be produced at Kjeller. As mentioned, the general devices for irradiating targets have until now been rather provisional. Three of the horizontal experimental channels have been reserved for isotope production, making possible the simultaneous irradiation of about sixty standard cans, each enclosed in a 20cm long graphite cylinder. In addition, a vertical channel has been inserted in one of the vacant fuel rod positions and used for long-time irradiations. At present the whole system is being reconsidered. In the future only vertical channels will be used for routine irradiations, because of the usefulness of the horizontal channels for research purposes. The isotope cans will be held in position by means of a long, vertical aluminium stringer which can be moved to a desired position to permit the loading or unloading of the stringer by a pneumatic system.

Closely connected with the isotope production is the consultative work carried out by our institute in order to facilitate the industrial uses of radio-isotopes. A number of industrial applications performed under this programme will be described at the present conference. The chemical separation methods used for the production of these isotopes are partly conventional, and partly new, e.g. for the separation of I^{131} from irradiated tellurium oxide and P^{32} from irradiated sulphur. Another interesting study is the production of P^{32} by irradiating large quantities of sulphur at the outside of the reflector where a large space is available and where the ratio of the rate of formation of P^{32} and P^{32} is high due to a high proportion of thermal neutrons.

Concerning the pile neutron yield of threshhold reactions a systematic study has been carried out especially for the $(n\alpha)$ reactions. This investigation shows that the yields of most threshold reactions earlier predicted and measured for unmoderated fission neutrons by Hughes apply well also for irradiations performed in the actual irradiation channels in the reactor core. Threshold reactions requiring very high neutron energies show, however, very reduced yields compared to those obtainable with fission neutrons. This is due to an obvious depletion of the very high energy part of the fission neutron spectrum in the irradiation channels.

The JEEP has also been used for investigating unknown isotopes or isotopes for which insufficient data exist. Several new fission isotopes have been discovered by irradiating uranium compounds and transferring the targets rapidly to an adjacent chemical laboratory with a simple pneumatic system mounted in one of the horizontal channels. The properties of the long-lived Nb^{94} produced by neutron irradiation of niobium have also been investigated.

A large number of irradiations of plant material, especially seeds of different kinds, have also been carried out, both in the reactor core and at the outer surface of the reflector. Both genetic and physiological effects have been studied. As compared with X-rays the pile neutrons have been found very efficient in producing genetic effects, and some experiments also indicate that a different spectrum of mutations is obtained. In order to control the dose measurements which to a large extent were carried out by the ferrous-ferric system, the influence of the linear ion density on the radiation yield of this system was investigated. The additivity of the effects of simultaneous action of lightly and densely ionising radiation was demonstrated. By exposing ferrous solutions to the nuclear fragments of different nuclear reactions and also to other types of radiations of known ion density, the variation of the G value (Fe^{3+}/100eV) with ion density was established.

Operational Programme and Staff.—Up to the present time, the reactor has been operated from Monday morning to Saturday morning, in three shifts. From this summer, however, continuous operation throughout the entire week, in four shifts, will be put into effect. Since the reactor is used for both physics research and isotope production, it has proved most convenient to run experiments which need low or variable power level, during the day, and to operate on a maximum power level for isotope production and for high power level experiments the rest of the time.

International Astronautical Congress

ALTHOUGH Russian delegates—Professor Ogorodnikov, an astrophysicist, and Professor Sedov, a gas dynamicist—for the first time attended an International Astronautical Congress, they did not deliver any technical papers. Their contribution was to hold a Press conference at which it was announced that Russia also would soon establish an artificial satellite. Nearly all the papers at the congress were concerned with the satellite; heating problems during its ascent, types of orbit and orbit correction, optimum entry trajectories and methods of observation.

A preliminary calculation of the temperatures which will be reached by an instrumented satellite was presented by L. Hansen, of Copenhagen. During ascent, the hull would reach 2200 deg. Fah., but the duration is so short that the interior will only be about 200 deg. Fah. When the satellite is revolving in its orbit the average temperature will be close to 25 deg. Fah., rising to a maximum of 230 deg. Fah. when in sunlight and falling to −210 deg. Fah. during eclipse. Insulation of the hull will produce greater external extremes while maintaining a more uniform temperature of the payload.

A paper by B. B. Langenecker, of Austria, discussed the use of metallic catalysts for lowering the ignition temperature and improving the heat yield from propellants. A direct result would be an increase in the temperature of combustion so that more effective cooling systems are required. It was suggested that the catalyst be arranged in the structure of a system of spirally twisted spokes within the combustion chamber and through the pores of which the fuel would be injected. Alternatively, the metal catalyst might be dispersed in a mineral oil fuel. Experimental study of these problems was suggested as a profitable line of research by bodies having limited funds.

At Ohio State University a study is being made, in the Aviation Physiology Laboratories, of the best methods of providing an artificial atmosphere for a sealed cabin. F. A. Hitchcock, from this laboratory, said that tolerance of human beings is such that carbon-dioxide must not exceed a partial pressure of 8mm to 10mm Hg and that the relative humidity must be below 40 per cent. Investigations are proceeding for the abolition of oxygen masks—now needed because pressure is developed from an air bleed from the engine or by nitrogen gas—and their alternative, individual pressure suits. Emergency escapes from high-altitude aircraft will be accomplished by ejection of the sealed capsule containing the pilot.

A paper by H. E. Newell of the Naval Research Laboratory, Washington, stated that in addition to the satellite vehicle many other American rocket firings would take place during the International Geophysical Year. A total of forty-five "Aerobees" and 120 "Rockoons" would be fired from locations ranging from the Arctic to the Antarctic. The earth satellite at 200 miles should be visible to the naked eye an hour after sunset, according to R. Tousey, also of N.R.L. Methods of determining its stellar magnitude were discussed and it was concluded that a pair of good binoculars could pick up a satellite about the zenith even if in an 800-mile orbit.

Mr. F. C. Durant, of Arthur D. Little, Inc., was again elected president of the I.A.F., and it was decided that next year's congress would be held in Rome.

Continental Engineering News

The European Cement Industry

Investigation by the O.E.E.C. Cement Working Party has shown that the annual rate of expansion of the industry, which was very rapid up to 1953, slowed down in 1954, although there are still a number of large scale projects for further increasing production. A survey made by the working party and recently published states that cement production in the member countries increased from 14,000,000 tons in 1923 to 25,000,000 tons in 1930, 36,000,000 tons in 1938, and 50,000,000 tons in 1951, i.e. to one-third of the world production in that year. By 1953, output in member countries had risen to 59,000,000 tons, reaching 62,000,000 tons in 1954. The industry is highly mechanised employing in 1950 about 80,000 workers. Labour costs amount to at most one-fifth of total production costs. The increase in production capacity in the last four years has not resulted in any substantial change in the numbers employed. In the main, all European requirements are covered from production, Europe being a net exporter of cement. Importing countries, among which the Netherlands rank foremost, buy most of their cement in adjacent member countries in view of the high relative cost of transporting this commodity. Consumption closely follows trends in general economic activity, particularly of course in the building industry, and has continuously expanded in the last four years. Exports rose to 13·5 per cent of production in 1953, but fell somewhat in the following year owing to an increase in home consumption. Prices, which are controlled only in Denmark, Italy and Norway, kept fairly stable in 1954. The report concludes that if the present construction programmes are continued and expanded, the prospects for the industry are fairly good, in spite of the drop in export and the uncertainty of foreign markets.

Radar on the Elbe

The preliminary work for installing radar at the mouth of the river Elbe has been completed. The plan is to enable all kinds of ships to find their way along the lower reaches of the river even in the densest fog. The radar network includes four stations, situated at the island of Neuwerk, in Cuxhaven, near Belum in Lower Saxony, and in Brunsbüttelkoog on the Kiel canal. Pilots will be equipped with portable wireless sets to receive ultra short wave instructions for holding the course.

German Atomic Reactor

In addressing the fifth annual convention of atomic scientists held recently at Lindau, Lake Constance, Professor W. Heisenberg (Göttingen) outlined the initial plans for atomic development in the German Federal Republic. These are concerned with the establishment of a research station which would be equipped with a reactor operating with uranium-238 and a graphite moderator. Of the total cost of the project of some DM.28,000,000, that of the reactor would amount to some DM.17,000,000. While smaller units could already be obtained commercially from United States firms for about DM. 1,200,000 to DM. 2,000,000, these reactors required uranium enriched with the isotope U235, or alternatively, heavy water, neither of which was available in Germany. Uranium mined in Western Germany could be supplemented comparatively readily from abroad, if necessary. The institute would probably be either at Munich or at Karlsruhe.

German Standards in Translation

The Deutcher Normenausschuss (German Standards Association), Berlin, W.15, Uhlandstrasse 175, and Cologne, Friesenplatz 16, has published a list of over 600 German standards which have been translated into foreign languages, most of them into English and Spanish, and some into French and Portuguese. The list is obtainable free from Beuth-Vertrieb G.m.b.H., Berlin W.15 and Cologne.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

GETTING USED TO THE COAL SHORTAGE

SIR,—Although, regrettably, I am not familiar with the ditty which provided so apt a title to your leading article on July 29th, I am, like most people, all too familiar with the effects of the prevailing coal shortage in this country. There is little doubt that the engineering industry will accept the possibility of a "perpetual fuel shortage" as a challenge to its ingenuity, and will unquestionably provide a solution to the technical problems associated with dwindling coal supplies. But that, surely, is a long-term affair, despite the rapid progress being made towards industrial applications of nuclear power. Have we really "gotta get used to" the shorter-term difficulties, the principal of which is the damaging effect of expensive coal imports on our balance of payments. I am fully aware that all engineers are not necessarily economists, but I nevertheless feel that engineers are deeply concerned about the country's present economic condition. That is the condition which is disturbing. It could be vastly improved if a greater quantity of the plentiful supplies of coal under these islands could be made available. More coal now need not hinder any of the efforts that are being made to get us used to doing with less!

J. WILLIAM

London, S.E.18.
August 5th.

Literature

Materials of Construction. By M. O. WITHEY and G. W. WASHA. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 72s.

THIS is an important and comprehensive book, running to over 800 pages, its joint authors being, respectively, the emeritus dean, College of Engineering, University of Wisconsin and the professor of mechanics in the same University. It deals with timber, building stone, structural clay products, cements, limes and plasters, concrete aggregates, mortar and concrete, cast iron, wrought iron and steel, alloy steels and non-ferrous metals and alloys. It is thus of direct interest to structural engineers and builders and the very informative sections on concrete apply to the wider field of general civil engineering, but no mention is made of asphalt and bitumen, constructional materials which are of immense importance in highway engineering, and which also concern the structural engineer and builder as roofing and waterproofing agents.

The book opens with a chapter on strength of materials, giving a concise summary of the standard textbook treatment of this subject, and this is followed by a well-illustrated chapter on testing machines which includes examples of apparatus for fatigue testing and also covers extensometers and strain gauges. The general subject of testing is discussed broadly, but here and there one could wish for more detailed information. For instance, in mentioning the well-known Amsler dynamometers in connection with the calibration of testing machines, it is rightly pointed out that temperature changes affect the readings of the mercury column, and that temperature effects must, therefore, be eliminated, but, in the absence of advice on this point, the uninformed student may well wonder how this is best accomplished. The preparation of test specimens is well described, however, and constant references are given to A.S.T.M. specifications. A very brief reference is made to stress analysis by photo-elastic methods, followed by an equally brief note on statistical analysis, the latter going no further than the elementary definitions which one would expect to find on the first page or so of any textbook dealing with this important subject.

Three chapters, totalling some 90 pages, are devoted to timber. Excellent structural timbers, such as southern yellow pine and Douglas fir, are readily available in the United States, and much research has been carried out in that country into the uses and preservation of wood as a structural material and the design of metal joints for structural members, which prevent the ends of wooden units coming into contact with one another. It is the points of contact necessitated by the direct jointing of wood to wood which are most frequently the areas where decay is most prevalent. In British civil engineering practice, as distinct from building construction, timber figures principally as a material for temporary works, but in the United States timber continues to be used as a permanent bridging material. The wider use of timber in that country probably accounts for the fact that this material is considered very fully, in all its aspects, in this book. Comprehensive tables of strengths and other properties are included, and it is interesting to note that the grading system in the A.S.T.M. and A.R.E.A. specifications includes a "1600 f" quality, for which the maximum safe fibre stress in bending, for dry timber, is as high as 1600 lb per square inch, compared with the "1200 f" grading recognised as high quality timber in the by-laws of the London County Council.

From the section dealing with bricks, one concludes that American testing practice for this material is much the same as British and it is pointed out, very correctly, that the crushing test of individual bricks, is of little value in determining the strength of a brick wall or column. Many years ago, our own Building Research Station published a great deal of test data which emphasised this same point. Mention is made of sand-lime bricks, and also of paving bricks, a "rattler" test being applied to the latter in a similar fashion to that described in the British Standard Specification for concrete paving slabs, but there appears to be no American product specifically described as an "engineering brick."

The book includes an excellent chapter on Portland cement from which the fact emerges that the composition of American "Portland" is practically identical with that of the British variety and, furthermore, that American cement testing procedure is very similar to ours, with one or two curious little exceptions. There is no mention, for example, of the special needle, surrounded by a circular cup, used in the British Standard test for final setting time, a plain needle being used in American practice for both the initial and final set, the latter being considered to have occurred when the needle "does not sink visibly into the paste." In an alternative test, due to Gillmore, two needles of different weights are used for determining the times of initial and final sets. A somewhat drastic test for soundness is described. In this, the cement paste is subjected to a temperature of 420 deg. Fah. in high-pressure steam and the resulting expansion is measured. This procedure should prove more searching than the well-known soundness test introduced by Le Chatelier and still widely used. Special cements are mentioned and this section of the book contains a quantity of valuable information, much of which is not ordinarily found in text-books on materials of construction.

Concrete aggregates are adequately treated, but grading particulars are naturally given with reference to A.S.T.M. sieves which, with the exception of the No. 200, have different mesh sizes to the same numbers in the British Standard series. A simple but effective method of estimating clay content is described and the caustic soda test for organic content is mentioned, but experience in this country has shown that this test is not infallible. A soundness test, involving repeated immersions of the aggregate in a solution of sodium or magnesium sulphate, followed by oven drying, finds no counterpart in British Standard Specifications, but seems to present useful possibilities. The proportioning, characteristics and testing of concrete mixes is dealt with very fully. The authors agree with the opinion widely held in this country that the slump test is really a measure of consistency, not of workability, and that no simple and satisfactory workability test has yet been introduced. In the tabulated list of different qualities of concrete for different types of work there is no mention, strangely enough, of the very high-grade quality, with a compressive strength in the region of 10,000 lb per square inch, now being specified for prestressed units, although such a comparatively recent development as air-entrained concrete receives attention. A very interesting note is given regarding fatigue tests and it is worth quoting the authors' statement that with concrete of an age of six months, or more, the compressive or flexural strengths under loads rapidly repeated for 2,000,000 cycles is approximately 50 to 55 per cent of the corresponding strengths under loading progressively applied to the point of failure. American opinion advocating the wider use of flexural tests echoes the view expressed by many British engineers, but we continue to differ over the relative merits of cubical and cylindrical test specimens for determining the crushing strength.

A large portion of the book is devoted to metallurgy. Blast-furnace practice is well described and very good descriptions are given of the Bessemer, open hearth (Siemens-Martin) and electric furnace methods of steel production. As far as structural steel is concerned the authors state that open-hearth steel is preferred in the United States as it is in Great Britain. The constitution of iron and steel is discussed clearly and in commendable detail, the theory of the iron/iron carbide diagram being presented with admirable clarity, for example, and much useful information concerning heat-treatment being included. An excellent chapter on alloy steels has been contributed by Professor Rosenthal, of the University of Wisconsin, and an equally good chapter on non-ferrous metals and alloys by his colleague, Professor Ragatz. In this section of the book the data relating to aluminium and magnesium alloys

for structural purposes is of particular interest.

In an effort to cover a very wide field within the restricted compass of a single volume of reasonable size, the authors have evidently been compelled to give somewhat brief treatment to certain parts of the book. Here and there the brevity is rather overdone, but, on the whole, the authors have done very well in compressing a vast amount of information into some 800 pages. The book deals, of course, with American practice, whereas in Great Britain the testing of constructional materials largely conforms with the methods given in British Standard Specifications which may, or may not, bear a close relationship to those of the A.S.T.M. If a full knowledge of the testing and properties of engineering materials is to be acquired, however, it is essential to abandon an insular mentality and become acquainted with established practice and opinions from beyond our shores. *Materials of Construction* can be recommended to British engineers and technicians who wish to widen their outlook by learning what is being done in the testing of materials on the other side of the Atlantic.

Structural Analysis. Second edition. By W. FISHER CASSIE. London: Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, W.1. Price 18s.

MANY authors of engineering textbooks written to-day make a point of pressing students to work out numerous exercises and to encourage them to do so, they fill their books with large numbers of worked-out examples and problems. Professor Fisher Cassie goes one step further: he suggests that the student should work out each problem for himself—afresh and without reference to the text. It is doubtful whether many students will find time to work through a quarter of the examples given them. Is it really necessary for them to do so? It is true that skill in solving problems, as in any other field, can only come with practice. But the University is not there to develop this type of skill but rather to train men to think and to supply them with the necessary basic principles to grasp the nature of the problems which may be presented to them.

Structural Analysis, Professor Fisher Cassie states, is particularly directed to engineering students who are in the last two years of a University or Technical College course, or who are studying with a view to becoming Associate Members of one of the engineering Institutions. The impression gained is that the book would be more useful to lecturers preparing notes; or to designing engineers in drawing offices. It is doubtful whether the book contains sufficient theoretical background to meet the needs of students without previous knowledge of hyperstatic structures.

The book, however, has the merit of being compact. It is devoted entirely to one subject—the solution of statically indeterminate structures,—and should be of considerable interest to specialists as it describes alternative methods of solving classical problems. Clapeyron's three moment equations are dealt with in some detail, as are the methods of strain energy, slope deflection, moment distribution and column analogy. Particularly interesting is the chapter on influence lines. It is, perhaps, a pity that more is not made of the elegant method of solving encastré arches by the elastic weights and elastic centre method. The chapter on model analysis might well have been expanded further.

The book is very attractively produced. The decimal notation of chapters and drawings gives it a pleasing appearance. The volume can be recommended to students who have already a standard work on statically indeterminate structures, to lecturers who wish to depart from routine lecture notes and to enthusiasts in structural engineering design offices who make structural analysis their hobby.

Titanium in Industry. By STANLEY ABKOWITZ, JOHN J. BURKE and RALPH H. HILTZ, Jr. London: Macmillan and Co., Ltd., St. Martin's Street, W.C.2. Price 36s.

THIS book, dealing with the technology of structural titanium, is intended to serve mainly as a guide to users of titanium and its alloys, and it is therefore written in a style which avoids unnecessary technicalities. It will, nevertheless, also prove to be of interest and value to metallurgists and research workers engaged in the development of the titanium industry, which has made such enormous strides in the last seven years. The authors are members of the staff of the Watertown Arsenal Laboratory, which has played an important part in the U.S. programme for the development of titanium, and are trustworthy exponents of the subject. The properties of titanium and of some of its more promising alloys are set out in detail, the principles underlying alloying and heat-treatment are discussed, and fabrication processes (hot and cold shaping, casting and powder metallurgy techniques, joining, machining and grinding) are fully described. Analytical and metallographic methods are reviewed because they are essential aids to inspection and quality control. The book is well illustrated with photographs and exceptionally clear diagrams, and there are twenty excellent photomicrographs from the Watertown Arsenal Laboratory. Difficulties and disadvantages attendant upon the fabrication and use of titanium and its alloys are frankly admitted, but there is no doubt that the future of the titanium industry is assured, and the authors, in dealing with the applications of titanium and its alloys, refer not only to existing applications, but to potential uses that will come into operation with the fall in the cost of titanium, which has already begun to take place.

One small historical point (which has nothing to do with the main theme of the book), may be mentioned. Aluminium, it is said, was "developed during the Napoleonic wars"; but impure metallic aluminium was not isolated until 1827 and its development cannot be said to have begun before 1854-55, i.e. during the Crimean war.

Vibration Problems in Engineering. Third edition. By S. TIMOSHENKO. London: Macmillan and Co., Ltd., St. Martin's Street, W.C.2. Price 65s.

IT is a great credit to Timoshenko that ever since the first edition appeared in 1928, his book "Vibration Problems in Engineering" has been regarded as the prime treatise on the subject. The appearance of the third edition can only strengthen that position. It is all the more remarkable in view of the large number of other books on vibrations that have been published since the war, but all these must still be regarded as secondary to Timoshenko's book on the more advanced aspects of the subject.

The third edition has been prepared with the collaboration of D. H. Young and an effort has been made to make the book more suitable for teaching purposes, particularly so in the first few chapters. The scope of the work has been kept much the same as before. The effort to make the book more usable for the student new to the subject is welcomed. A good balance has been achieved between solving problems by formal mathematical methods and explaining the significance of the terms by vectors. The first chapter dealing with one degree of freedom problems has been much improved. Numerous problems have also been added. It is regretted that not more emphasis is given to the concept of "equivalent" systems for replacing more complicated multi-mass systems with several restraints by a simplified system which is more readily analysed. A student could not be expected to appreciate the significance of problem 3 on page 15 from the preceding subject matter. The answer to this problem would seem to be in error, the correct value being 0·158 second. The problem is discussed more fully towards the middle of the book on page 242. It should be omitted from the earlier section. Non-linear systems and variable spring characteristics are now dealt with in one chapter instead of two and much new material has been added. A good innovation is Chapter III on systems having two degrees of freedom as an introduction to the more advanced work with many degrees of freedom.

It is very revealing that it has been found necessary to omit the use of the Lagrangian Equations in order to make the book more suitable for undergraduate work. The chapter on vibrations of elastic bodies has been much revised and extended. A fuller discussion on the effects of rotatory inertia and shear on the vibrations of beams with different end conditions would have been appreciated. Why the value of the constant k^1 for a rectangular cross-section on page 335 has been changed from $\frac{2}{3}$ to 0·833 is not clear.

The appendix dealing with vibrations measuring instruments has been omitted. This third edition should enhance the popularity and continued success of this book for many years.

Symposium on Sinter. London: Iron and Steel Institute, 4, Grosvenor Gardens, S.W.1. Price 37s. 6.—Sintering of material for the blast furnace was originally applied to flue dust but, as the supply of high grade ores was depleted, became the means of economic utilisation of fine ores and concentrates. From small beginnings over 30 years ago, the sintering of iron ore has become an integral part of the manufacture of pig iron. About a quarter of the total iron content charged into the blast furnaces of this country is now in the form of sinter, and this proportion is still increasing. In view of the growing importance of sintering and the fact that many valuable papers were due to be written on the subject, the Iron and Steel Institute arranged for a symposium to be held in November, 1953, and the papers then presented, together with three more recent papers, have now been published, with the discussion, as Special Report No. 53. The papers fall into three groups: the sintering process (physical and chemical principles), the production of sinter (mainly concerned with sintering plant), and sintering practice. Thus, all aspects of the subject are covered. The relative merits of sinter and natural ore have been a matter of discussion, especially in America, but there can be no doubt of the advantages of sintering when applied to fine ores. Several papers illustrate the benefit which follows the increased use of sinter even to the extent of a 100 per cent sinter burden. An outstanding paper, descriptive of achievement, is one recording the work carried out at Appleby-Frodingham. The papers as a whole present a very valuable review of the present position of the theory and practice of sintering, and incidentally reveal some deficiencies in existing knowledge of the subject. They will enable the engineer to recognise more clearly the problems associated with sintering practice and the probable course of future developments.

Exhibition of Peaceful Uses of Atomic Energy at Geneva

No. II—(*Continued from page 192, August 5th*)

AS stated in last week's article, two exhibitions are being held from August 8th to 20th, concurrently with the Geneva Conference on the Peaceful Uses of Atomic Energy. The first exhibition, which is of scientific interest and is intended to appeal mainly to members of the delegations attending the international conference, is being held in the Palais des Nations. Here the United Kingdom Atomic Energy Authority has a display which deals mainly with nuclear reactors for research and for power generation and with instrumentation for nuclear work. The other exhibition is in the Palais des Expositions and is open to the general public as well as delegates. Here the whole British effort in the development of peaceful uses of atomic energy is represented; besides the U.K. Atomic Energy Authority, thirty-four British firms from heavy industry and the instrument industry are among the exhibitors. Two of these groups of exhibits are briefly described below.

Equipment and specimens designed for research into the mechanical properties of graphite at high temperatures are among the exhibits shown by The General Electric Company, Ltd., Kingsway, London, W.C.2, to illustrate work which is being done by the company's research laboratories on behalf of the Atomic Energy Research Establishment, Harwell.

The main item in this group of exhibits is a high-temperature, high-vacuum furnace, with special facilities for measuring the creep properties of graphite specimens and making cinematographic records of the results.

This furnace (Fig. 9) was designed to operate at temperatures up to 2200 deg. Cent., and to maintain a good vacuum at these temperatures. The difficulty of finding suitable refractories which are strong enough and sufficiently good thermal and electrical insulators at temperatures above 1800 deg. Cent. led to the use of a robust, self-supporting heating element surrounded by radiation shields. Since most of the heat loss at these temperatures takes place by radiation, this arrangement effects considerable economies in power. The element is a slotted graphite cylinder with a wall thickness of 9mm which can be machined quite simply. The furnace tube is preheated at 2500 deg. Cent. before assembly in a stream of pure argon to remove volatile matter. The radiation shields surrounding the element serve the dual purpose of reflecting and redistributing the heat emitted, and are made of 0·5mm molybdenum sheets and 0·2mm tantalum sheets. Current is led in through copper electrodes provided with a circular groove into which the end of the graphite element fits. The mild steel case is externally water cooled and is fitted with water-cooled "Pyrex" window cells for observation and filming of the test specimens. The electrode blocks and vacuum seals are also water cooled. A 15kVA power supply is available for heating the furnace from a single-phase step-down transformer controlled by three ganged 5kVA "Variac" transformers connected in parallel. Approximately 15kVA is thus available at a maximum voltage of 15V and a current of 1000A.

A 1S50 "Speedivac" rotary pump is used to back an O3B "Metrovac" oil-diffusion pump, forming a pumping system which has enabled a vacuum of 10^{-4}mm of mercury to be maintained with the charge at 2000 deg. Cent.

The graphite specimens (Fig. 12) in the form of coiled springs (enabling a length of 1m to be tested in a small working space) are suspended from a Mumetal stack contained in a glass tube sealed to the top of the furnace; the specimens can be raised, lowered and turned within the furnace chamber by a magnetic field. The graphite for the coiled specimens is manufactured on a laboratory scale simulating large-scale production methods, and is then extruded, formed into a coil and baked at 3000 deg. Cent. The springs are heated in the furnace and stressed, and their extension is filmed automatically once per minute during a twelve-hour test period.

The General Electric Company, Ltd., is also showing an electron synchrotron (Figs. 7 and 8) for the cyclic acceleration of electrons to a high energy. The electrons are injected into the evacuated glass annulus ("donut"), at an energy of 70keV, from a thermionic cathode mounted in an electron "gun" which is pulsed so that electrons are only injected into the orbit for 5μ second in each cycle of the operation. The initial acceleration follows Betatron practice, where, due to the increasing central accelerating flux and the guiding field, the electrons are accelerated in a fixed orbit; the betatron acceleration is limited to a value of 2–3MeV by the saturation of the centre pole. The remaining acceleration is carried out by the electron receiving a pulse of energy (100eV) at each revolution when the electron passes across the gap of a resonator excited at 500 Mc/s. Having been accelerated to an energy of 30MeV, which corresponds to a speed of 99·98 per cent of the velocity of

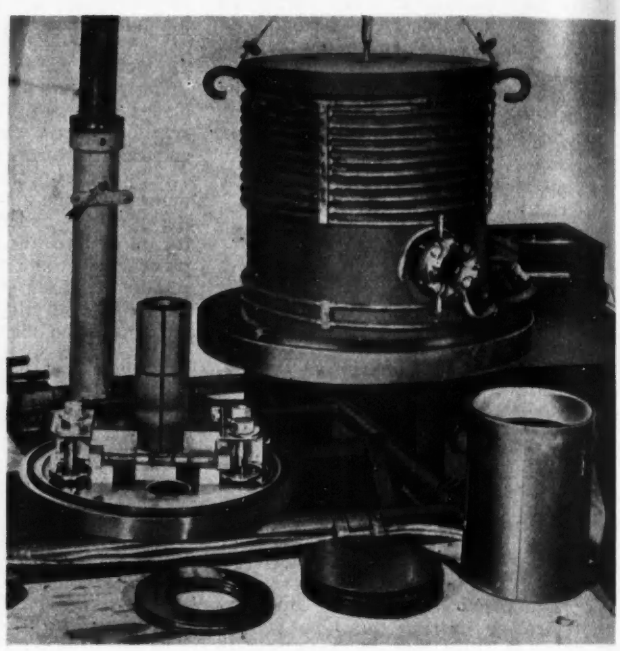


Fig. 9—High-vacuum furnace for research into the properties of graphite moderator materials

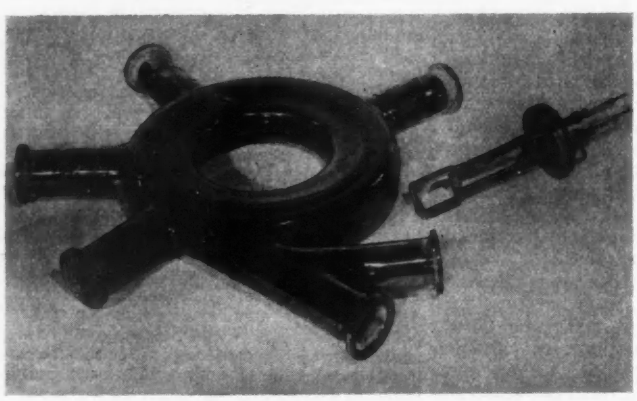


Fig. 7—Glass "donut" and resonator forming part of an electron synchrotron

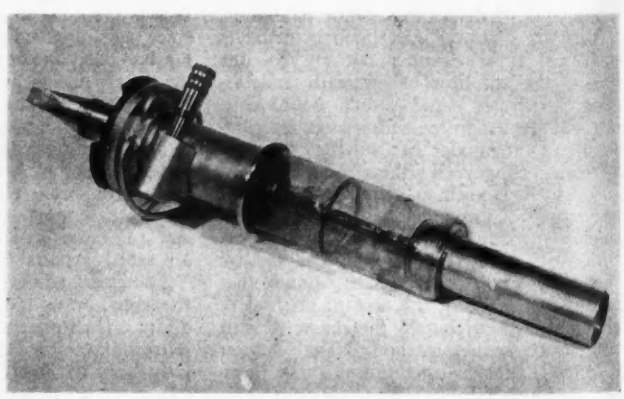


Fig. 8—Electron gun

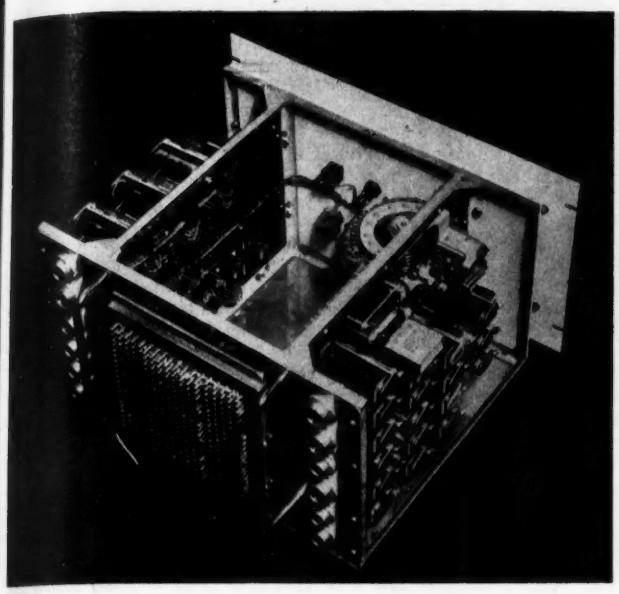


Fig. 10—The sequence control unit of "Analmatic" laboratory uses some of the techniques of automatic telephony based on selector switches and relays

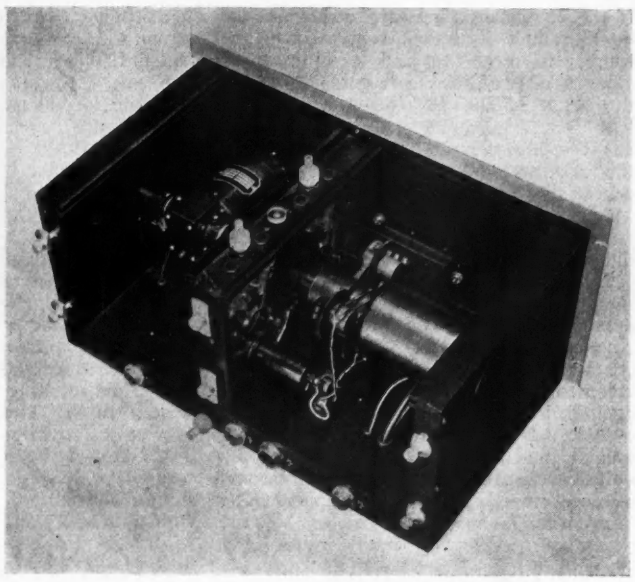


Fig. 11—The function of analysis in the "Analmatic" laboratory is carried out by the absorptiometer and photomultiplier unit shown here

light, the electrons can then either be extracted from the "donut" through a foil window, or the orbit can be expanded in such a way that the electrons strike a tungsten target to give hard X-rays for deep therapeutic work. The machines operate on a 50 c/s supply and the complete injection, acceleration, and extraction occupy ¼ cycle.

An advantage with this particular electron gun is the ease of replaceability of the cathode assembly, enabling a filament to be replaced in 10 minutes. Experiments can thus be carried out with both wide and narrow beam assemblies. Provision is also made for altering both the injection radius and angle by micrometer adjustment without breaking the vacuum. The gun uses a thoriated tungsten emitter which enables the gun to be opened to the air without harm to the cathode.

To ensure that the electrons shall not be deflected from the orbit by residual charge on the walls of the "donut," the walls are coated with a conducting material (gold) to give a resistance of approximately 6 ohms across the "donut." The thickness of the gold layer is approximately 300ÅU, that is, twelve millionths of an inch.

Models of furnaces and furnace pots used for uranium processing at the Springfields plant of the Atomic Energy Authority are also being shown on the G.E.C. stand. These furnaces at Springfields are vertical cylindrical electrical furnaces designed for the conversion of ammonium di-uranate to uranium tetrafluoride which is then reduced to metallic uranium. The furnaces have a rating of 100kW, a maximum temperature of 750 deg. Cent., a heated depth of 6ft 6in and are cooled by forced air circulation.

The company is also showing recent developments in the electromagnetic transducer system introduced by Salford Electrical Instruments, Ltd. Transducers such as these have been used for the remote indication of pressures and temperatures in Great Britain's atomic factories, particularly in the gaseous diffusion process at Capenhurst where the fissile isotope, uranium-235 is extracted from uranium-238.

To illustrate the system the company is demonstrating a method of using electromagnetic transducers for measuring the distortion of a partially evacuated tank: movement of the tank wall is shown in thousandths of an inch on a remotely positioned indicating instrument. By the addition of a simple pressure-responsive element the instrument indicates and records the degree of partial vacuum within the tank itself.

Automatic Laboratories

A good example of a highly developed form of instrumentation is to be seen in the "Analmatic" automatic laboratory which is being shown by the United Kingdom Atomic Energy Authority under the title "special instrumentation for atomic research." The equipment exhibited was designed and made by Baird and Tatlock (London), Ltd., in co-operation with the Atomic Energy Research Establishment, Harwell. It is intended specifically for the continuous analysis of liquors containing uranium, but other forms of automatic laboratory can be made for various analytical tasks.

The term "Analmatic" is a portmanteau word denoting automatic analysis and "Analmatic" laboratories are intended to relieve the scientist of the work of routine analysis. Operating continuously, one such laboratory can replace three skilled men working an eight-hour shift.

Generally an "Analmatic" laboratory consists of one or more standard units designed to carry out a specific laboratory procedure, or to replace the manual and mental processes of the trained human operator who is normally employed to carry out such laboratory procedures. These units are assembled, with their power supplies and auxiliary services, in standardised cabinets in such a way that the required process is performed and the results are recorded without human aid.

The "Analmatic" laboratory illustrated in Fig. 13 is designed to analyse continuously a liquor sampled from four different sources.

Fig. 12—Typical helical specimen of graphite processed for research work in the high-temperature furnace shown in Fig. 9

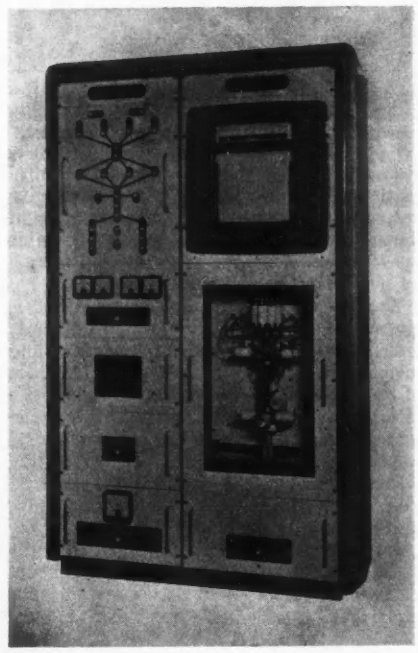


Fig. 13—"Analmatic" laboratory designed for the automatic and continuous analysis of liquors containing uranium

In this equipment a measured volume of the liquid sample is drawn from each of the sources in turn. In each case measured volumes of two different reagents are added to the sample and the whole is reduced with hydrogen. The liquid is then examined in an absorptiometer and the result, showing the concentration of the element in grammes per litre of liquor, is recorded on a chart. The recorder has two separate ranges and, according to the concentration of the sample, the proper range is selected automatically.

Referring to Fig. 13, it will be seen that the "Analmatic" laboratory consists of a number of units arranged in two vertical bays in a single cabinet. The left-hand bay contains five units: a graphic panel with coloured lights to show the state of the equipment at any instant in the operating cycle; a master control unit; a sequence unit; a time pulse unit; and an e.h.t. supply unit for the absorptiometer which in this instance embodies a photomultiplier. The

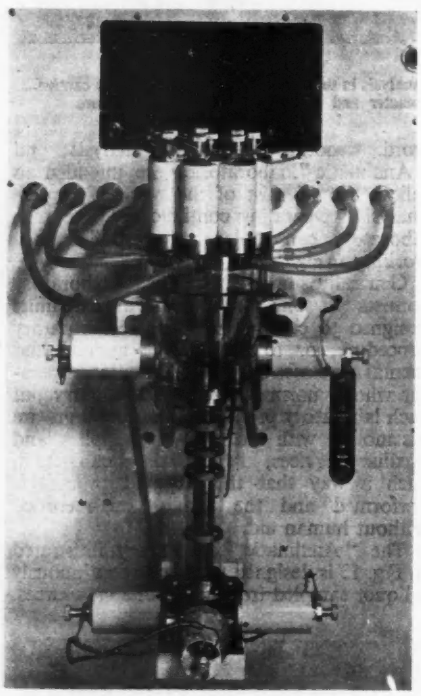


Fig. 14—Metering and mixing unit of the "Analmatic" laboratory. All the valves are electrically operated under the supervision of the sequence control unit

sequence unit and the time pulse unit control all the operations of the laboratory and give an indication of any fault that may occur in the apparatus. The right-hand bay contains the chart recorder, the metering and mixing unit, and the absorptiometer.

A view of the sequence control unit is given in Fig. 10. Its main component parts are a Post Office selector switch and relays whereby control of the whole sequence of operations is effected with the same basic techniques as are used in automatic telephony. In controlling the sequence of operations, this unit confirms that each operation is completed correctly before the next operation starts; in effect the sequence control unit must receive a feed-back signal to signify correct operation after every stage of the operation. At the same time the sequence control unit causes the lights on the graphic panel to be illuminated stage by stage as the operation proceeds.

A fault alarm is arranged to work in conjunction with the sequence control unit. If the sequence of operations is interrupted for any reason or if any operation has not been completed correctly, then no feed-back signal will be received and the next stage will fail to be initiated; instead an aural and visual alarm will be given and the operation will be stopped until the fault has been cleared. The faulty circuit can be identified with the help of a fault-finding multi-point switch which connects each main electrical circuit in turn to a pilot light.

The metering and mixing unit of the laboratory (Fig. 14) consists of a transparent mixing vessel fitted with a number of electro-magnetically-operated valves. The whole assembly is designed to measure a given quantity of a sample liquor, to add accurately measured quantities of reagents, to mix them, to reduce with hydrogen, and to discharge the resulting liquid to the absorptiometer. In Fig. 14 the admission valves for the sample and reagents can be seen arranged in a circle above the mixing chamber; the central valve controls the entry of washing water. The horizontally disposed valves near the middle of the apparatus are for gas admission (left) and exhaust (right). The horizontal valves at the foot of the column are for discharging the final liquor. All the valves are electrically-operated as determined by the sequence control unit.

In the equipment with which we are concerned here the analysing unit (Fig. 11) consists of an absorptiometer which compares the sample liquor (received from the metering and mixing vessel) against a standard and, with the help of a photomultiplier, expresses the result as an electrical signal which is capable of being recorded on a chart.

(To be continued)

Notable Locomotives of 1905

By E. C. POULTNEY, O.B.E.

THE evolution of British locomotive power as a result of the practice followed by different railways over the years has always been an attractive subject, and, when recalling the principal developments during the year 1905, now half a century ago, much will be found of moment as indicating the path then being followed by designers in an effort to provide for the growing needs of the railways. Looking back, interesting innovations are seen to include the introduction of the first six-coupled 4–6–0 engine for fast passenger traffic on the London and North Western and consideration being given to compound expansion by H. A. Ivatt at Doncaster, and at Gorton by J. G. Robinson, of the Great Northern and Great Central Railways respectively. For the Midland, R. M. Deeley who, in January, 1904, had succeeded S. W. Johnson as locomotive superintendent, built the first of the modified three-cylinder 4–4–0 compounds, the forerunners of an extensive class of successful engines, and G. J. Churchward introduced for service on the Great Western two further four-cylinder compounds of French origin, later named "President" and "Alliance." These locomotives followed the compound "La France," which had been placed in traffic during the year 1903 and which, it will be remembered, also came from France, being, like "President" and "Alliance," a product of the Société Alsacienne de Constructions Mecaniques, Belfort. Concurrently, a number of "Atlantics" of Churchward's design were also turned out at Swindon. A further development causing no little interest was seen in the 4–4–2 four-cylinder compound express locomotive, built experimentally for the Great Northern by the Vulcan Foundry, Ltd., thus the G.N.R., like the G.W.R., acquired a locomotive designed and built by an "outside" firm.

L.N.W.R. Engine "Experiment"

The new 4–6–0 express passenger locomotives (Fig. 1) known as the "Experiment" class, designed by G. Whale, at Crewe, were specially intended for handling heavy and fast passenger services between Crewe and Carlisle. The 4–4–0 "Precursor" class, built in the first place in 1904, were successfully handling this traffic over the relatively easy London-Crewe division of the main line, but experience showed that something of greater power was required to negotiate the much more difficult Northern Division involving the severe gradients between Carnforth and Shap Summit northbound, and, in the reverse direction, the 31 miles of heavy climbing from Carlisle up to Shap.

Generally, the 4–6–0 engines were similar to the "Precursors," having the same sized cylinders, 19in by 26in, and the same steam pressure, 175 lb per square inch, but with smaller wheels, 75in, as against 81in diameter, the tractive force was proportionately greater. The boiler heating surfaces were rather larger and the firebox, carried over the centre coupled axle, was shallower and had a grate area increased from 22·4 to 25·0 square feet. The motion was like that used for the "Precursor" class, including Joy's valve gear operating balanced valves above the cylinders. The crank axle was of the built-up pattern with the crank webs extended to form balance weights. The first of these engines, No. 66,

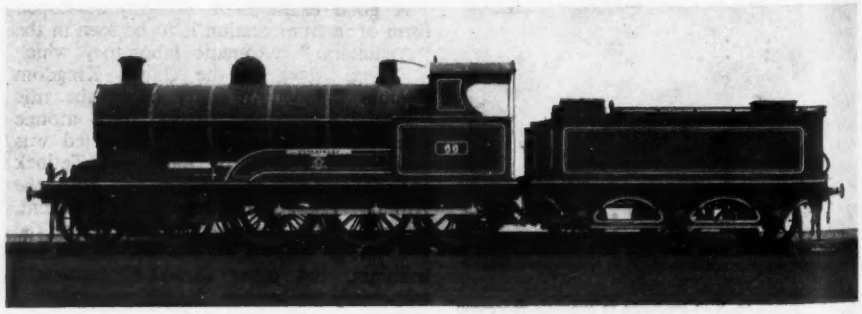


Fig. 1—L.N.W.R. engine "Experiment" intended for handling heavy and fast passenger services

"Experiment," was turned out of the Crewe works in May, 1905, and on the 21st of the same month ran a trial trip from Crewe to Carlisle and return with a train of empty coaches weighing, exclusive of the engine and tender, 393½ tons.

Writing in THE ENGINEER of November 10, 1905, C. Rous-Marten recorded a journey from Crewe to Carlisle with the engine "Experiment" and a train of 320 tons, constituting the 10 a.m. Scotch Express ex London (Euston), when the run from Crewe to Preston, start to slow pass, took 54 min 26 sec for the 51 miles, equal to a mean speed of 56·2 m.p.h. and, from passing Preston to a stop for signals at Tebay, the time was 64 min 4 sec for the 53–25 miles, equal to an average speed of 49·7 m.p.h. Starting from Tebay at the foot of the Shap bank, in bad weather, the engine ascended the Shap incline at a speed of 27·2 to 27·7 m.p.h. From Shap Summit to Carlisle the time was 29 min 41 sec for the 31½ miles, downhill for the greater part of the distance, giving a speed of 63·8 m.p.h. During the descent some high speeds were recorded; the maximum was not stated at the time, but was subsequently given as being 93 m.p.h.

In view of the extensive locomotive tests carried out during recent years by British Railways, it is of interest to recall that an engine of the "Experiment" class took part in some investigations made by Dr. F. J. Brislee, of Liverpool University, with the object of examining the combustion process in locomotive fireboxes when working under normal operating conditions. For this purpose, gas sampling apparatus was fitted to enable the collection of samples of the products of combustion from the smokebox. The results of these experimental investigations were communicated to the Institution of Mechanical Engineers in 1907. More recent experiments of the same kind, conducted by Dr. P. Lewis-Dale with an L.M.S. 4–6–0 passenger engine, class "5XP," formed the subject of a paper communicated to the Institute of Fuel and printed in THE ENGINEER of February 5, 1937.

Midland Engines

The Midland locomotives introduced during 1905 were the first designed by R. M. Deeley, after succeeding S. W. Johnson as locomotive superintendent. They were of the 4–4–0 type for passenger service on a "simple" two-cylinder engine with inside cylinders (Fig. 2), and the other (Fig. 3) a three-cylinder "compound" generally similar to the engines of 1901–2, built at Derby by S. W. Johnson. The former engines in general also resembled Johnson's latest of the same class; in fact, the cylinders, which had W. M. Smith's patent piston valves operated direct by Stephenson's valve gear, were identical.

The boilers, of the Belpaire pattern, were also similar, but carried a higher working pressure of 200 lb per square inch compared with the 180 lb per square inch for Johnson's engines. A distinctive feature of the Deeley engines was the fitting of a much more commodious cab, giving better protection to the enginemen, and the provision of six-wheeled tenders in place of the large double-bogie, eight-wheeled design fitted to the earlier locomotives. Interest was, however, chiefly centred on the Deeley compounds which, while being, as already mentioned, largely based on the Johnson compounds of 1901–2, had, however, some very important differences. The original engines were constructed on W. M. Smith's system featuring three cylinders, one h.p. and two l.p., and three sets of valve gear which could be independently controlled,

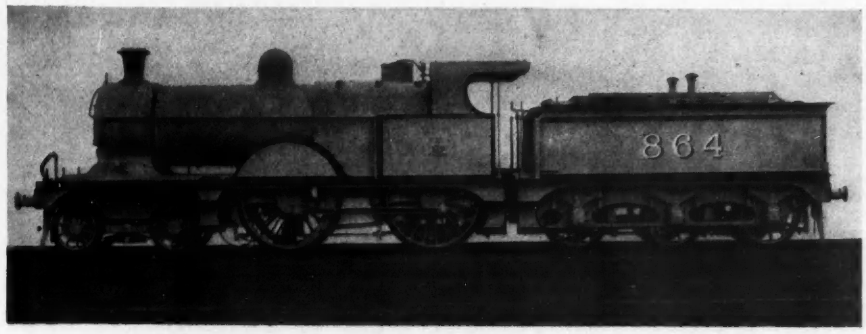


Fig. 2—Simple two-cylinder 4-4-0 engine designed by R. M. Deeley for M.R.

thus enabling the h.p. and l.p. cut-offs to be varied in respect to each other.

For starting purposes, a reducing valve, manually operated, was provided, which was one of the principal points of Smith's system. This valve could be used to supply boiler steam to the l.p. steam chests for starting, and it could also be adjusted to maintain steam at a given pressure in the l.p. steam chests while the engine was working as a compound. This was called working semi-compound and increased the power output, if required for any reason. The Deeley modifications consisted, in the first place, of doing away with the independent control of the three valve gears and, secondly, the introduction of what is described as the "Deeley regulator," whereby upon the first movement of the engine driver's control, steam was allowed to flow direct to the l.p. cylinders and also through a small port in the regulator valve to the h.p. cylinder. The engine, therefore, started as a two-cylinder simple and then, by reason of the fact that steam was also passing to the h.p. cylinder, the engine automatically proceeded as a semi-compound on account of the h.p. exhaust passing to the l.p. cylinders. Further movement of the regulator handle had the effect of shutting off the supply of boiler steam to the l.p. cylinders and of increasing the regulator opening to steam for the h.p. cylinder and the locomotive was, therefore, "compounded." These simplifications have since become standard for all the many three-cylinder compounds more recently built for the Midland and subsequently for the L.M.S. Railway by Sir H. Fowler. The Deeley compounds worked with a steam pressure of 220 lb per square inch furnished by a modified boiler, in which there was a larger grate having an area of 28·4 square feet as against 26 square feet for the original Johnson compound engines.

G.N.R. Compounds

H. A. Ivatt's Doncaster-built compound engine, No. 292 (Fig. 4) was the first of this type to be turned out of the Doncaster Works. This was really a standard large-boilered "Atlantic" of the "251" class, fitted with four cylinders compounded and having a working steam pressure of 200 lb per square inch as against 175 lb per square inch for the standard two-cylinder engines. The h.p. cylinders, outside in the usual position, were 13in by 20in, while, inside and in line with the outside pair, there were two 16in by 26in l.p. cylinders. Four sets of valve gear arranged for independent adjustment of cut-offs were fitted, Walschaerts gear outside and Stephenson's inside. A special starting,

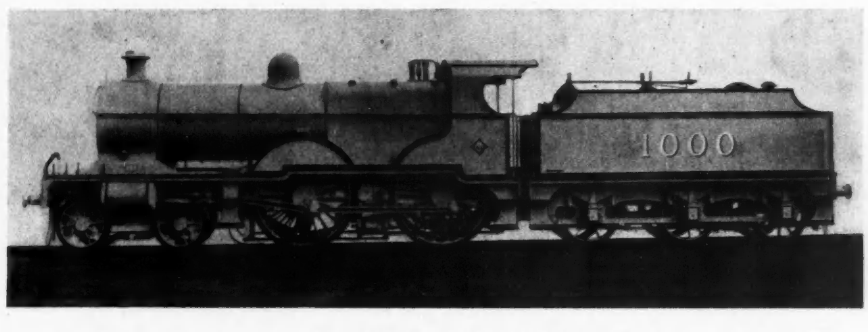


Fig. 3—Compound three-cylinder 4-4-0 engine designed by R. M. Deeley with Deeley regulator for M.R.

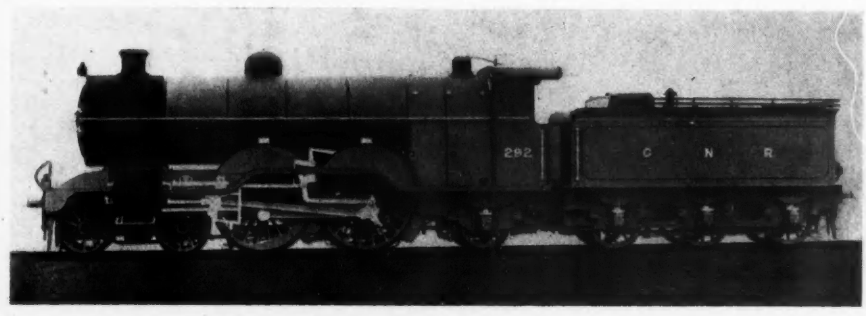


Fig. 4—Ivatt's four-cylinder compound engine for the G.N.R., the first of its kind to be made at Doncaster

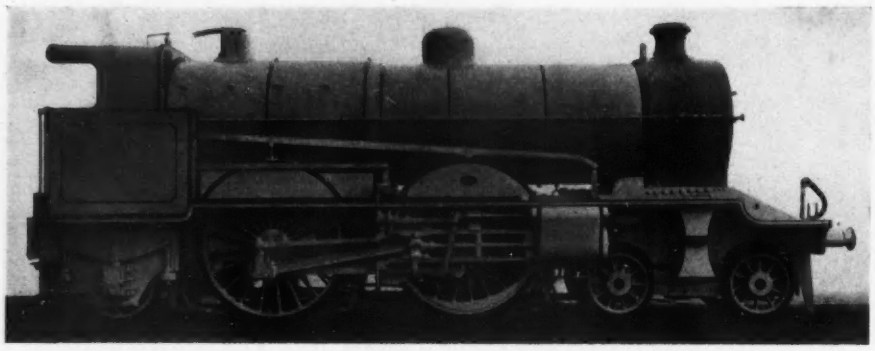


Fig. 5—Four-cylinder compound engine for the G.N.R., built by Vulcan Foundry

or "change valve," as it was called, was fitted, which allowed boiler steam to be used in all the cylinders at starting and enabled the h.p. cylinders to exhaust direct to the blast pipe. The drive was divided, the h.p. being connected to the rear driving wheels, while the inside l.p. cylinders drove the leading pair of drivers through the medium of a crank axle.

The four-cylinder compound engine built by the Vulcan Foundry (Fig. 5) for the Great Northern was supplied as the result of an invitation sent out to locomotive builders specifying the duty required and asking them to build engines—compound or otherwise—

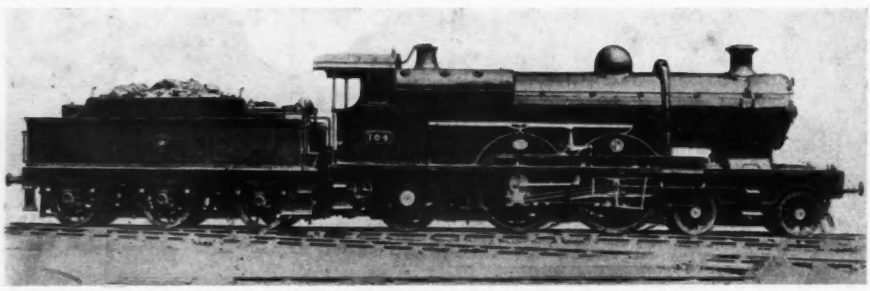


Fig. 6—French-built, De-Glehn four-cylinder compound engine for the G.W.R., later named "Alliance"

for trial purposes on the Great Northern. In accordance with this requirement, a contract was entered into with the Vulcan Foundry, Ltd., for a four-cylindered balanced compound of the 4–4–2 type, designed to operate fast express passenger services in competition with Ivatt's "Simple" and "Compound" Doncaster-built engines having the same wheel arrangement. Though the engine was furnished by the Vulcan Foundry, Ltd., embracing the maker's suggestions for the general design of the engine considered suitable to meet the specified requirements, it complied in some respects, particularly in the design of the leading bogie and certain standard fittings, with Doncaster practice at that time. The two h.p. cylinders placed outside the frames were arranged between the rear bogie and leading driving wheels, and the l.p. pair were inside below the smokebox. The h.p. cylinders had a diameter of 14in and the l.p. 23in, the common stroke being 26in. The drive was divided, the h.p. connecting with the rear driving wheels and the l.p. the leading drivers. Thus, the general arrangement followed French practice, and, like the French design, four sets of Walschaerts valve gear were employed, but controlled by the Vulcan patent reversing gear permitting the independent adjustment of the h.p. and l.p. cut-offs. A Vulcan starting valve also was part of the equipment, the purpose of which was to allow boiler steam at reduced pressure to be supplied to the l.p. steam chests and turn the h.p. exhaust direct to the blast pipes to facilitate starting.

The boiler tubes were of the "serve" pattern, giving a heating surface of 2344 square feet, to which must be added 170 square feet for the firebox, thus making the total 2514 square feet. The working steam pressure was 200 lb per square inch, as for the Doncaster compound. This engine, together with the Ivatt compound and a standard large "Atlantic" "251" class, took part in a series of trials carried out between London (King's Cross) and Doncaster, for which purpose the boiler working pressure for the simple expansion "Atlantic" was raised from 175 lb to 200 lb per square inch. The results were communicated by H. A. Ivatt to the Institution of Mechanical Engineers in 1907, and showed little difference in the coal required per gross ton-mile per hour. The Vulcan compound required 0·133 lb of coal and the Ivatt compound and the standard simple "Atlantic" consumed 0·126 lb and 0·131 lb of coal per gross ton-mile. The gross ton-miles per hour were given as 16,759, 17,337 and 17,030 for the Vulcan and Ivatt compounds and the Ivatt simple "Atlantic" respectively. The Vulcan compound, therefore, did slightly less work in comparison with the other two locomotives.

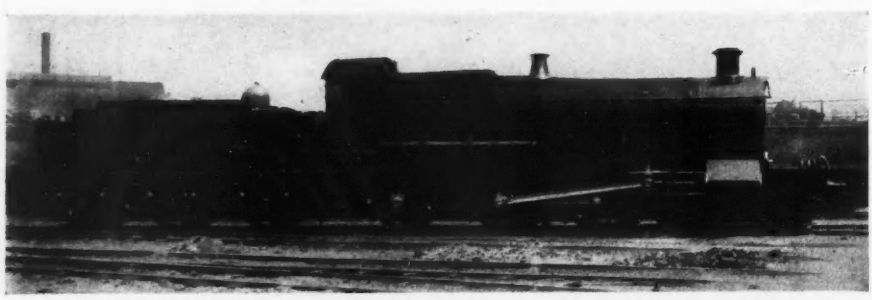


Fig. 7—G.W.R. 4-4-2 locomotive. Ten of these engines were constructed in 1905

G.W.R. "President" and "Alliance"

While little seems to be generally known regarding the working results obtained with the French compound "La France," which went into service on the Great Western late in 1903, it would appear that the engine was to some extent favourably regarded, because in June, 1905, two more French-built four-cylinder compound engines were delivered for working fast passenger services. These engines, No. 103 and 104 (Fig. 6), later named "President" and "Alliance," were much larger than "La France," but had the same wheel arrangement—that is, they were of the 4–4–2 type. The coupled wheels, like "La France," had a diameter of 80·5in; the cylinders were, however, larger, the h.p. pair being 14$\frac{3}{16}$in diameter and the l.p. 23$\frac{3}{4}$in. The stroke common to all the engines was 25$\frac{3}{16}$in. A feature of the boilers was the grate area of 33·3 square feet, which was large for a firebox of the narrow kind. Very little was ever made known concerning the working results obtained with these compounds.

Contemporarily with the arrival of these compound locomotives, further engines for fast passenger traffic were being turned out at Swindon. Of these, some were 4–6–0 and others 4–4–2, ten of the latter being constructed during 1905, one of which—No. 181, "Ivanhoe"—is illustrated in Fig. 7. The 4–6–0 resembled "Albion," No. 171, as first built and the 4–4–2 engines were very similar to "Albion" after being converted to an "Atlantic" prior to trials with the French compound 4–4–2, "La France."

Marsh "Atlantics"

A development on the Brighton line exciting some interest in 1905 was the introduction of some "Atlantics," designed by D. E. Marsh and built by Kitsons, of Leeds (Fig. 8). Marsh, who had been manager of the G.N.R. Locomotive Works, at Doncaster, had at the time recently been appointed as chief at Brighton and his new engines were so like Ivatt's large "Atlantics," they could have been built to the same drawings and possibly were—at any rate, to a large extent. There were, however, a few differences; the cylinders, as a case in point, were larger, having a diameter and stroke of 18$\frac{1}{2}$in and 26in, comparing with Ivatt's 18$\frac{1}{2}$in by 24in, and the boiler pressure was 200 lb, comparing with 175 lb per square inch for the G.N. engines. It was in the boiler that the greatest similarity was seen, both designs having a wide firebox of the round top pattern. The Marsh boilers had slightly less heating surface than the Ivatt design, the total amounting to 2473·5 square feet, of which the tubes accounted for 2337·5 and the firebox, 136 square feet, comparing with a

total of 2500 square feet for the G.N.R. engines, made up of 2459 and 141 square feet for the tubes and firebox. The grate areas were 31 square feet for the Marsh and 30·9 square feet for the Ivatt boilers respectively.

The introduction of these relatively large engines on the Brighton line marked a considerable advance on the 4–4–0 engines designed by R. J. Billinton, the later class of which weighed 49 tons, engine only, comparing with the 67 tons of the Marsh "Atlantics."

Great Central Compounds

In all, four compound engines were constructed at Gorton for the G.C.R. from J. G. Robinson's designs, the first of which was completed in 1905. The design was really the Robinson standard two-cylinder "Atlantic" class, fitted with three cylinders compounded on W. M. Smith's system. These compounds had a 19in by 26in h.p. cylinder between the frames and two l.p. cylinders outside, 21in by 26in. They were, therefore, the same size as for the Midland compound engines; the arrangement was, however, different in that the G.C.R. engines had a divided drive, the single h.p. cylinder connecting to the leading wheels through the medium of a single throw crank axle, the l.p. driving through the trailing pair. There were three sets of Stephenson's valve gear, one operating direct a piston valve for the h.p. cylinder, and two sets for the two l.p. cylinders, which had slide valves. The Smith patent reducing and starting valve was also fitted. The normal working pressure for the standard two-cylinder "Atlantics" was 180 lb, but the compounds had the steam pressure raised to 200 lb per square inch.

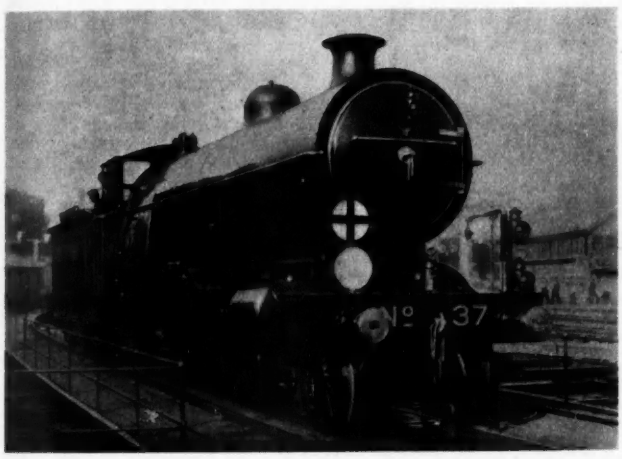


Fig. 8—A "Marsh Atlantic" for the Brighton line. These engines were very similar to G.N. "Atlantics" designed by Ivatt

In common with the G.W., G.N. and the L.B.S.C. railways, the G.C.R. was giving considerable attention to the "Atlantic" locomotive for fast passenger traffic, and the latter received during the year under review a number of the Robinson standard "Atlantics" from the North British Locomotive Co., Ltd., which, it may be remarked, carried, like the Gorton-built compounds, the higher working steam pressure of 200 lb per square inch.

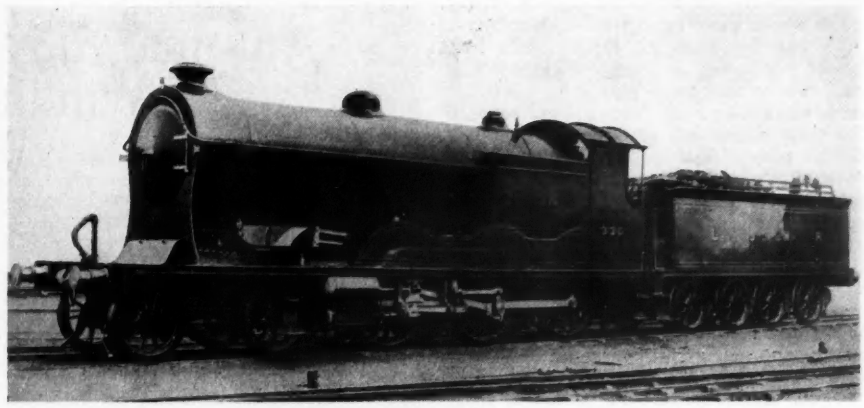


Fig. 9—Four-cylinder 4-6-0 locomotive for L.S.W.R. designed by Drummond. Feed heating equipment was installed in the tender

Drummond's L.S.W.R. Four-Cylinder Engines

For working the heavy West of England passenger services over the London and South Western Railway between London (Waterloo) and Exeter, D. Drummond designed and constructed at Nine Elms some large four-cylinder engines of the 4–6–0 type (Fig. 9) the first with this wheel arrangement to be used on this railway.

The four cylinders were each 16in diameter with a stroke of 24in and were placed two inside below the smokebox and two outside between the trailing wheels of the leading bogie and the leading pair of coupled wheels. The inside pair drove the leading coupled wheels through the medium of a built-up balanced crank axle, and the outer pair drove the intermediate pair of coupled wheels. Four sets of valve gear were employed, comprising two sets of Stephenson's gear operating slide valves placed between the inside cylinders, and for those outside Walschaerts gear operated slide valves arranged below the cylinders. A power-operated reversing gear was used, a novel feature of which was the use of two separate reversing engines, one for the inside and one for the outside valve gears. The reversing engines consisted of the usual steam and hydraulic cataract cylinders, the latter being for the purpose of locking the gear. The boiler, pitched very high with its centre line 9ft 6in above the rails, had a total heating surface of 2727 square feet, of which the tubes, 340 in number and 1¾in diameter, contributed 2210 square feet, and the firebox no less than 517 square feet; the greater part of this was, however, due to an installation of 112 cross water tubes, a feature of Drummond's practice. In this case, the tubes, in two nests of 56 each, furnished a heating surface of 357 square feet, so that the firebox itself had 160 square feet of heating surface.

The grate area was 31·5 square feet. The firebox was carried over the intermediate and trailing coupled axles which accounted for the highly pitched boiler centre. The Drummond water tubes had an outside diameter of 2¾in, and extended across the firebox, slightly inclined, the two nests being inclined in opposite directions. The outer wrapper plates opposite the ends of the tubes were cut out and fitted with box-like seatings for cover plates, detachable for examination purposes. To support the covers against the loading imposed by the boiler steam pressure, transverse stays were threaded through some of the tubes and secured to the cover plates on each side of the firebox. Like other passenger engines designed by Drummond, large eight-wheeled double bogie tenders were used, a distinguishing factor of which was the use of inside frames for the bogies with, in consequence, inside axleboxes somewhat reminiscent of Stroudley's practice on the "Brighton" line. It will be recalled that he used inside frames for the six-wheeled tenders of his "Grosvenor" and

Notable Locomotives of 1905 *: Principal Dimensions*

Railway type	L.N.W.R. 4-6-0	M.R. 4-4-0	M.R. 4-4-0	G.N.R. 4-4-2	G.N.R. 4-4-2	G.W.R. 4-4-2	G.W.R. 4-4-2	L.B.S.C.R. 4-4-2	G.C.R. 4-4-2	L.S.W.R. 4-6-0
Cylinders: dia. and stroke, in ..	2. 19×26	2. 19½×26	1. H.P. 19×26 2. L.P. 21×26	2. H.P. 13×20 2. L.P. 16×26	2. H.P. 14×26 2. L.P. 23×26	2. H.P. 14½×25½ 2. L.P. 23½×25½	2. 18×30	2. 18½×26	1. H.P. 19×26 2. L.P. 21×26	4. 16×24
Driving wheels, dia. in	75	81	84	80	80	80·5	80·5	79·5	81	72
Steam pressure, lb per sq. in ...	175	200	220	200	200	227·6	225	200	200	175
Rated tractive force, lb	18,600	20,760	—	—	—	—	23,090	19,200	—	25,400
Heating surfaces, sq. ft:										
Tubes	1,908	1,310·5	1,320	2,359	2,344†	2,582	1988·65	2337·1	1,778	220
Firebox	133	145·0	151	141	170	173	154·26	136·4	153	517*
Total	2,041	1455·5	1,471	2,500	2,514	2,755	2142·91	2473·5	1,931	2,727
Grate area, sq. ft	25	25	28·4	30·9	31·0	33·4	27·07	31·0	26·0	31·5
Weights, working order, tons										
On driving wheels	46·75	35·48	39·1	36·5	37·0	37·2	39·0	37·75	37·0	52·5
Engine	65·75	53·52	59·8	69·0	71·0	71·7	70·5	67·0	71·0	73·0
Tender	37·0	41·43	42·9	40·9	40·9	36·75	43·65	29·5	48·3	42·0
Total	102·75	94·95	102·7	109·9	111·9	108·45	114·15	96·5	119·3	115·0

Note: * Includes water tubes. † Serve tubes. Compound locomotive. Vulcan Foundry.

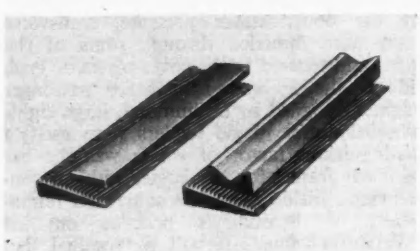
" Gladstone " locomotive classes. A further point about these large tenders worthy of note was the fitting of Drummond's feed heater equipment and, in connection with this, two vertical steam pumps for the boiler feed water fitted on the engine between the main frames just in front of the firebox throat plate. The heater itself consisted of a long rectangular tank fitted below the main tender tank, containing a number of small diameter brass tubes fitted into headers at each end of the heater tank. Steam from the locomotive cylinders was passed through the tube nest, so heating the water passing through this supplementary tank on its way from the inlet to the pump suction outlets at the opposite end of the heater. The water formed by any steam condensed on passing through the tubes was drained away from the rear header, while any remaining steam not condensed escaped to atmosphere by a discharge pipe fixed at the rear of the tender. A number of South Western locomotives were fitted with this feed heater arrangement and savings in coal consumption are said to have reached, in some instances, 6 lb of coal per mile. One other point which may be mentioned is the fact that at the time these large locomotives were built they were the heaviest in the country, with a weight, engine only, of 73 tons.

The leading dimensions of the locomotives mentioned in this review of the more interesting examples introduced during 1905 are given in the table on page 233. With the exception of the L.N.W.R. passenger engine " Experiment " and the Vulcan Foundry Company's compound locomotive, for the photograph of which the writer is indebted to the builders, all the illustrations are from photographs furnished by The Locomotive Publishing Company, Ltd.

Adjustable Packings

WE illustrate below a design of easily adjustable packing which has been introduced by Rubert and Co., Ltd., Chapel Street, Stockport, Manchester, 19, for use on lathes or for other applications where a steplessly variable range of height adjustment is required.

As can be seen, the packing consists of two plate members. The larger, wedge-shaped, base-plate has serrations milled at an angle along its inclined top face. The smaller upper plate has its base machined with similar serrations and to a complementary angle to the base member. When



Pairs of flat and vee packings adjustable for height

the two members are placed together the uppermost and lowermost faces are parallel and the mating serrations provide a non-slipping grip when a load is applied. Fine height adjustments can be made by sliding the upper plate along the inclined serrations of the base-plate. The upper plates can, as shown, be made in vee block form as well as with flat upper surfaces.

These flat packing sets are made in four sizes, in two lengths of 2½in and 4½in by 1in wide, and with adjustable heights from $\frac{1}{16}$in to $\frac{7}{16}$in ; and two lengths of 3in and 6in by 1½in wide and with height adjustment from $\frac{7}{16}$in to $\frac{5}{8}$in. The four vee slot sets have similar dimensions and their respective heights from the base of the bottom of the vee groove are adjustable over the same ranges.

Automatically Operated Skip Winding Gear

AFTER lying abandoned for almost thirty years, the Neuhof-Ellers potash mine near Frankfurt/Main was put back into operation last year. Owned by Wintershall A.G., of Kassel, the mine has been equipped with a skip winding gear which can be operated fully automatically, and is claimed to be the first of its kind in the world. The work was carried out by the Skip-Compagnie, Essen, in which are grouped the three firms of Demag, Duisburg, which built the mechanical part, Siemens-Schuckert, which supplied the main motor and its Ward-Leonard control, and Siemens and Halske, Essen, which produced the signalling and control installations.

Planned to be constructed in two stages, of which the first was completed in 1½ years, the winding gear is designed for an ultimate capacity of 612 tons per hour (present capacity 300 tons per hour). The tippler station is situated at a depth of 539m, and the hoist travels to a depth of 597m. Fig. 1 shows the layout of the installation.

With a winding speed of 14m per second, the total cycle, including stops, is stated to take 72 seconds. When the second motor has been installed, this figure is expected to be reduced to 70·5 seconds, the average winding speed remaining the same.

At present the carrying capacity of the winder is 6000 kg. The equipment is driven by a d.c. motor rated at 1010kW, with an effective torque of 22 metric tons, and revolving at 44·6 r.p.m. By adding a second similar motor later, the capacity will be doubled. The Ward-Leonard control consists of a 1270kW, 600V generator coupled to a 1120kW, 990 r.p.m. converter motor which, in turn, is connected to

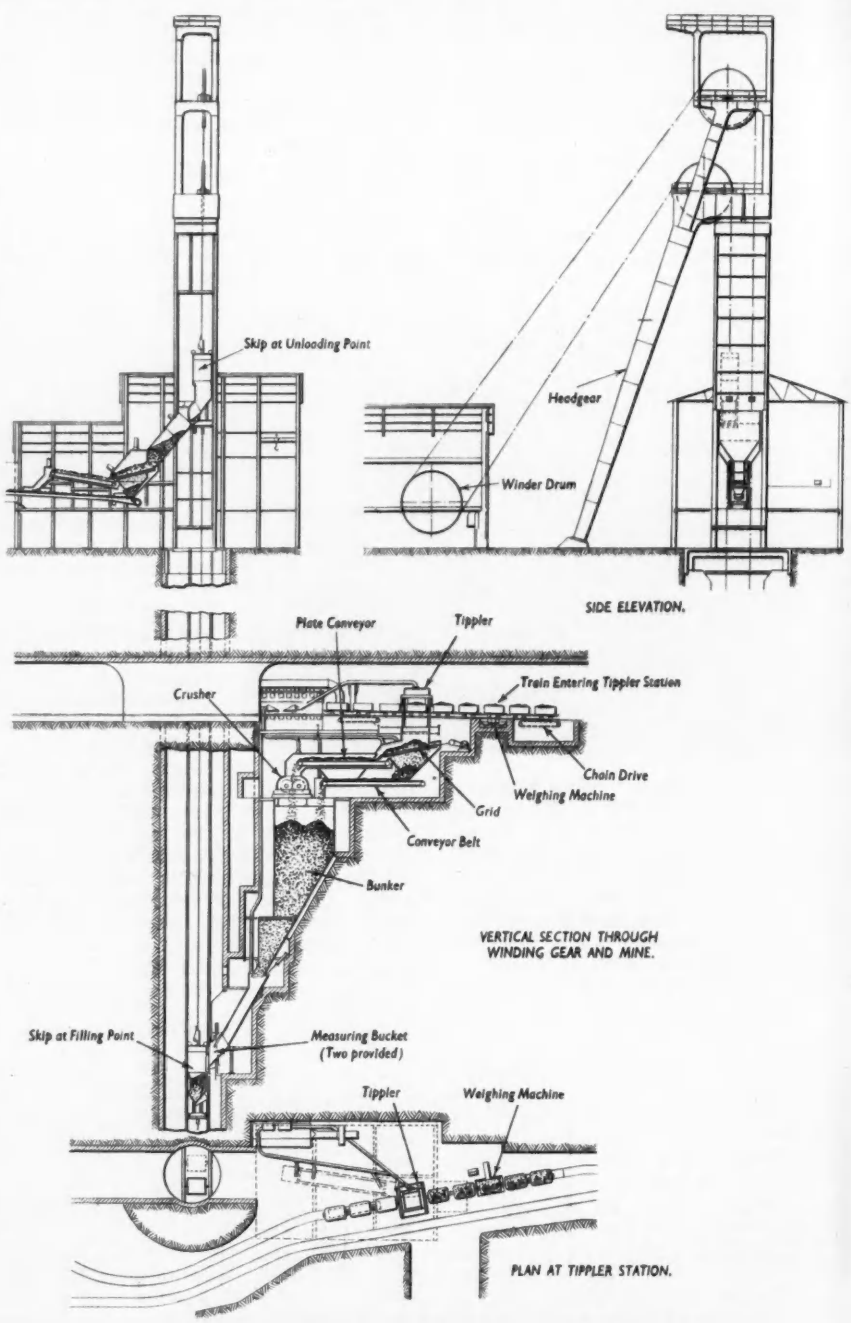


Fig. 1—Layout of Neuhof-Ellers winding gear for a potash mine

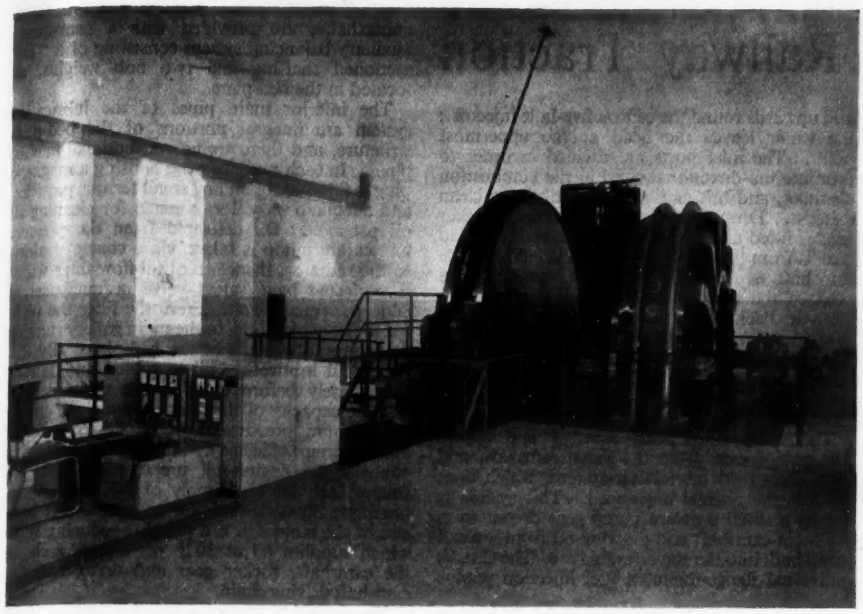


Fig. 2—Winder motor and drum, with control desk on the left

5·5kV, 3-phase mains. Fig. 2 shows the winder motor and drum together with the control desk for manual operation which is always used for the carrying of people.

Fig. 3 illustrates the headgear which is designed to take 240 tons, the ultimate breaking load on the ropes when the second stage of construction is completed. The electrically welded wheels of 5500mm (18ft) diameter are arranged one above the other. Each is designed for a working load on the rope of 30 tons.

One aspect which had to be considered in the design was the wooden lining of the shaft, which could not be altered. As shown in our illustration, Fig. 4, the skip is equipped with pneumatic-tyred guide wheels which run on the wooden guides. Fixed shoes are additionally provided which do not normally come into contact with the guides but wedge on to the thickened ends of the beams if permissible travel of the skip is exceeded. Spring-loaded safety clamps are also fitted which engage with the guide beams if the rope should break. When open, the lid of the skip forms a rear wall which during loading helps to guide the salt into the skip. In the closed position it forms a platform on which seventeen people can be transported.

At the filling point is the wagon tippler which can deal with trains of up to twenty cars holding 3 tons each. These trains are brought by electric locomotive and hauled into and out of the tippler by chain drives. After being weighed the cars are tipped one at a time. They are fitted with rotary couplings, so that it is unnecessary to uncouple and re-couple the trains.

Fig. 3—Headgear with two rope pulleys of 5500mm diameter

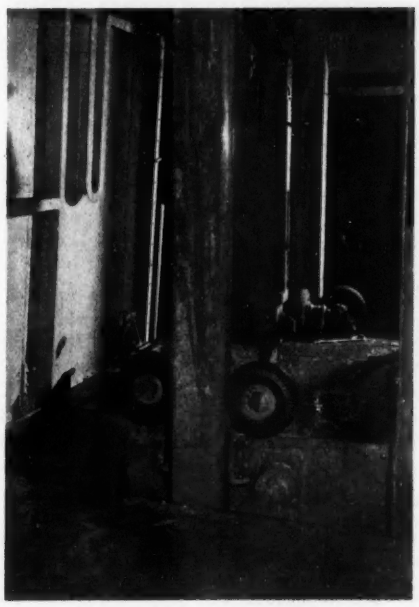


Fig. 4—Top of skip showing pneumatic-tyred guide wheels, guide shoes and safety clamps

From the tippler the salt falls over a chute on to an inclined transporter grid. The fines drop through and are carried by a conveyor to a storage bunker, while the large pieces are delivered by the grid to a crusher which reduces them to 3in to 4in before they, too, reach the bunker. This bunker holds 500 cubic metres (approximately 650 tons) of salt and serves as a buffer between the tippler station and the skip hoist. It discharges into two inclined measuring buckets which have the same volume as the skips.

All equipment for filling the skips is remotely controlled by compressed air. By means of limit switches and time relays the operations are carried out in such a manner that there is always a measuring bucket ready to fill the arriving empty skip. The filling, hoisting and discharging of skips is carried out as a fully automatic sequence of operations.

Automatic Safety Control System for Locomotives

A PROBLEM on railways when operating electric locomotives controlled by a single driver alone in the cab is that of safety of the train should the driver be taken ill, let his attention wander or even doze whilst still keeping the train in motion. Various systems of automatic train control, dead man's handles, &c., have been introduced to overcome these dangers, and following an extensive study of the problem an interesting safety and vigilance control apparatus has been developed by the Oerlikon Company in Switzerland. This apparatus is fitted to the locomotive and is designed to give the fullest possible measure of safety to trains under the control of one man whilst not adding in any way to his duties. It is designed to sound a warning bell at the end of predetermined intervals during which the driver has had no occasion to manipulate his main controls. If no attention is paid to this warning the power is automatically cut off and the train brought to a stop. The apparatus is now being made under licence in this country by Davies and Metcalfe, Ltd., of Romiley, near Leeds.

The "space-interval" safety apparatus, as it is known, can be fitted to any design of locomotive and it is driven through worm gearing from one of the axles. A system of gears in the mechanism rotates a camshaft through an electro-magnetic coupling, the gear ratio being such that the cams rotate slowly in proportion to the distance travelled by the train. The cams through roller followers and links are connected to the train compressed air brake and electrical system. The camshaft is spring loaded to its starting position and disengagement of the magnetic coupling, which is effected by operation of any one of the normal driving controls on the locomotive, momentarily frees the camshaft and permits it to return to its start setting. If the camshaft is not returned it rotates on until a roller follower is lifted and sets a warning bell ringing in the driver's cab. If a resetting release movement is not then transmitted further contacts are made and the power is automatically cut off and the air brakes applied on the locomotive. It will be appreciated that the space-interval to which the mechanism can be set can be adjusted through suitable cams in accordance with the route conditions and the service in which the locomotive is operating.

The mechanism is connected to the controller, a pedal switch and the pneumatic brake gear of the locomotive and operation of any one of these three controls automatically re-sets the mechanism to the start of a space-time sequence. Thus under service operating conditions any normal manipulation of the controls by the driver anticipates and cancels the current and starts a new interval sequence. On a relatively long run where no control operation has been required the end of the interval is announced to the driver by the warning bell. He can then re-set the apparatus by any one of four methods—a momentary release of the safety or dead man pedal; operation of the master controller; operation of the valve of his automatic brake; or by a slight operation of his direct brake valve. If none of these controls is operated owing to the indisposition or inattention of the driver, power is cut off and after a short interval emergency braking of the train automatically begins.

KARIBA HYDRO-ELECTRIC SCHEME.—The World Bank has indicated its willingness, in principle, to participate in the finance of the Kariba hydro-electric project on the Zambesi river, the Federal Prime Minister, Lord Malvern, has announced. The total cost of the Kariba scheme is estimated at £85,000,000. The next step, Lord Malvern said, would be for the Bank to make a thorough technical appraisal of the Kariba project.

Diesel Engines for Railway Traction

A CONSIDERABLE amount of development work on diesel engines for railway traction has been carried out during recent years by Davey Paxman and Co., Ltd., and the firm has now introduced a series of engines from 750 to 2000 b.h.p. specifically for main line service locomotives. This range of "Y.L." and "Y.L.X." engines is built with eight, twelve and sixteen cylinders of vee design with an angle of 45 deg. between the banks of 9½in by 10½in cylinders. The engines are built in naturally aspirated and pressure-charged models of 1000 r.p.m. as a standard. To suit them for locomotive installation a compact arrangement was considered necessary particularly at cylinder head level. This width is restricted to 70in in the naturally aspirated engines and 74in in the pressure-charged engines, with a dimension considerably less at the frame structure. Heights, too, are quite moderate, being 27½in below crankshaft centre line and 62in above it. The rotational speed of 1000 r.p.m. also is high enough to prevent disadvantageous effect on the main generator size and weight when diesel-electric propulsion is favoured. The specific fuel consumption is very even and is stated to vary only from 0·385 lb to 0·375 lb per brake horsepower-hour the whole way down the full-load scale from 1000 to 475 r.p.m.

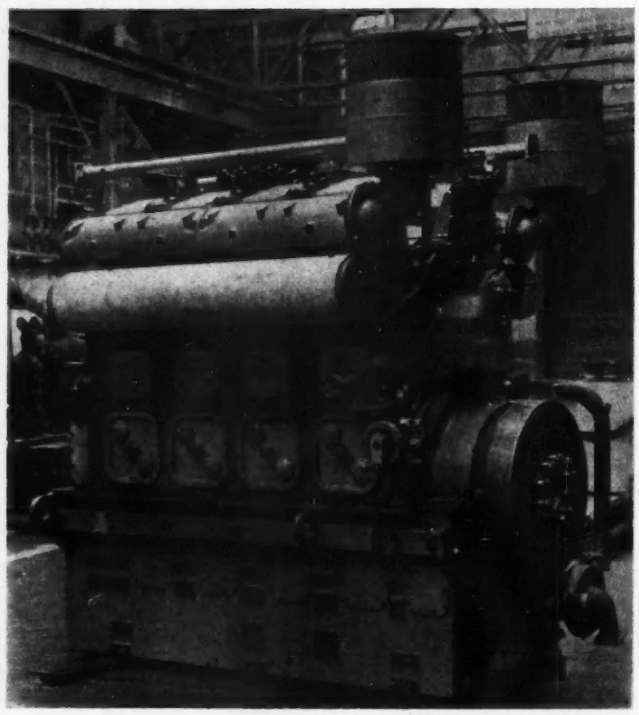
In the naturally aspirated form the compression ratio is 15 to 1 and the full-load firing pressure about 950 lb per square inch; in pressure-charged engines the compression ratio is lowered to 12·8 to 1. Injection pressure is about 3500 lb per square inch. Respective specific outputs at 1000 r.p.m. are 6·93 and 9·73 b.h.p. per litre in naturally aspirated and pressure-charged engines.

In these "Y.L." engines the bed-plate, which also forms the sump, is stress bearing and carries the main bearings as well as the mounting feet. The crankcase-cylinder block above is also a one-piece welded steel structure for all models, and, like the bed-plate, is fully stress relieved. Large aluminium covers on each side of the crankcase-cylinder block give access to the main and big-end bearings. These inspection covers are fitted with crankcase explosion doors, set to blow open at 20 lb per square inch; this pressure gives no distortion and the doors automatically clamp down again immediately the pressure wave is over, and so prevent ingress of air. Pressed aluminium inspection covers are fitted for inspection of the water jackets and cooling water piping connections.

The water jackets are separate heavily galvanised units surrounding the cast iron liners, and by this means the cooling water is kept away from the welded steel crankcase-cylinder block. Any water leaking past the "Neoprene" ring sealing the bottom of the water space does not drain into the crankcase, but into a chamber from which the drainage is to atmosphere.

Each cylinder head is an iron casting housing two inlet and two exhaust valves. A double deck is cast in the cylinder head to deflect the water at high velocity past the exhaust valves and upwards round the central five-hole injector; the water leaves the head at the uppermost point. The inlet ports are divided in order to promote uni-directional swirl in the combustion chamber, and this assists in maintaining a clean exhaust. Drop forged aluminium valve rocker gear is fitted and the lubrication of the overhead gear is from the engine main system. The single camshaft is located in an oil trough in the neck of the vee and driven by a duplex chain from the back end of the crankshaft. There are two cams per cylinder, and each is keyed to the shaft by two taper keys. The shaft itself is in one piece, and runs in thin-walled, steel-shell, white-metalled bearings. The cam followers are die cast aluminium bronze.

The fuel injection pump camshaft and tappets are gear driven from the valve camshaft, and have their own lubrication system, which does not use the normal engine oil. This system is fed by a small pressure pump gear driven from the main camshaft and drawing oil from a small sump built into the engine crankcase. The C.A.V. individual flange-mounted fuel injection pumps are carried in two groups parallel to the cylinder centre lines on a shelf above the main camshaft trough. The fuel lift pump is driven from the free end of the injection pump driving shaft, through two small flexible couplings and an intermediate shaft.



Eight cylinder "YL" diesel engine for railway traction

A single-piece forging of EN12Q steel is used for the crankshaft, the webs having balance weights as needed by the various four-throw, six-throw and eight-throw models. A double bearing is provided at each end of the shaft to support the weight of the main generator at the back end, and to support the weight of the viscous vibration damper and give adequate support for auxiliary drives at the forward end. All bearings are interchangeable, except a single flanged locating thrust bearing, and they are of steel shell copper-lead-lined design. Fork-and-blade connecting-rods are fitted and have attached to the foot a block, housing the copper-lead shell crankpin bearing. This block has a chromium-plated external surface on which the shell bearing of the blade rod rides. The "8YL" and "8YLX" engines, with four-throw crankshafts, are provided with a gear-driven auxiliary balancing system consisting of a "D" sectioned shafting and two bob weights, all located in the bed-plate.

The interior main pipes of the lubrication system are integral portions of the bed-plate structure, and there are no conventional interior pipes. In each main bearing housing a magnetic plug is fitted to retain any small ferrous particles, and adequate provision is made for cleaning all oil passages. Oil delivered from the pressure lubricating pump is taken, via a coarse strainer, to the radiator, thence to a full-flow filter which is protected by a safety valve normally set to 80 lb per square inch. From the filter the oil is fed to the cooler, then to the main gallery running down the full length of the bed-plate. By this means all lubricating oil is cooled and filtered immediately before entering the main gallery, and the capacity of the filter is enough to ensure a minimum pressure drop, moderate velocity and optimum efficiency. A pressure-relief valve controls the engine oil pressure at 50 lb per square inch for the supply of oil to the main bearings, big-ends and the governor. At each end of the main line is a pressure-reducing valve which supplies oil at 10 lb per square inch to the camshaft, rocker gear and drive, and the camshaft driving chain.

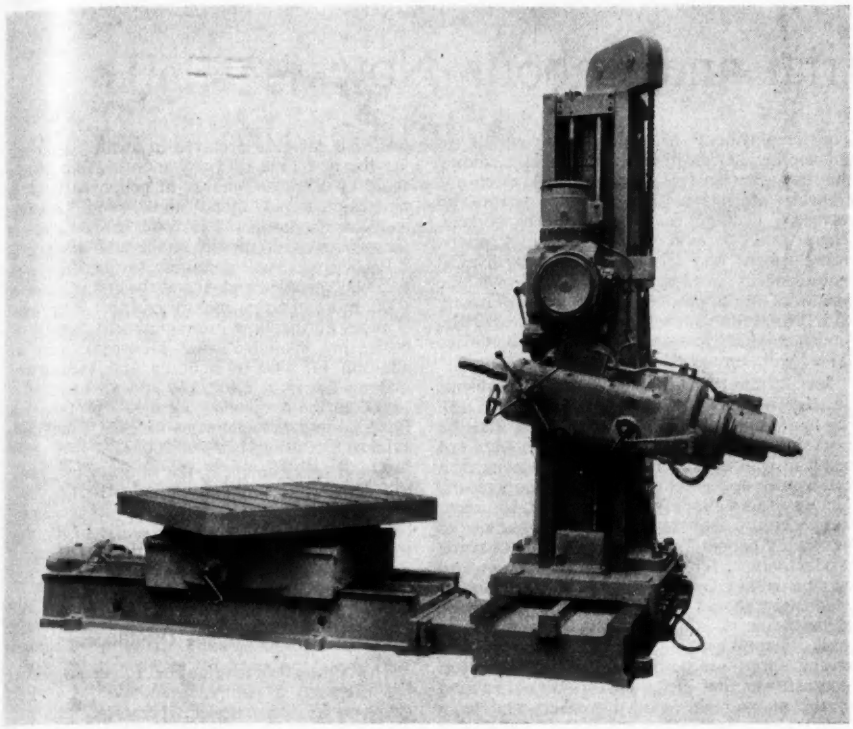
Two exterior water circulating pumps (one in the eight-cylinder engines) are gear driven from the free end of the engine, and inlet manifolds are mounted in the cylinder housing and a flexible connection is tapped off the manifold and connected to each cylinder liner individually. Outlet manifolds are connected to the heads by short lengths of pipe and flexible connections, and are located above the vee between the cylinder banks.

A centrifugal hydraulic servo governor driven by bevel gears from the drive end of the main camshaft, uses engine lubricating oil as its operating medium. Incorporated within the governor casing are three solenoids which normally provide a range of eight different engine speeds.

A torque control regulator, which operates in conjunction with the engine governor consists of a hydraulically operated rheostat, the movement of which is regulated by a torque control valve within the governor. This torque control valve includes two moving elements provided with ports, which are linked to the engine rack control shaft and the governor speed setting lever respectively. A change in external load causes the engine governor to change its position, thereby affecting the relative positions of the torque control valve elements, and uncovering ports to feed the hydraulic motor driving the rheostat, thus causing it to rotate in the direction necessary to adjust the electrical load until it is equal to the rated engine output. Pressure charging, using Napier turbo-blower groups, is used on the eight-cylinder and twelve-cylinder "YLX" models, which have two turbo-groups, and the "16YLX" engine, which has four. Valve overlap in these pressure-charged engines is 130 deg.

Part standardisation has been extensively introduced and about 75 per cent of all wearing parts are standard throughout the five engines in the range. In this way, the firm states, one stock of spares can be made sufficient to cover a railway's requirements for locomotives ranging from heavy shunters up to the large main line engines.

FORMING OF ALUMINIUM SHEET.—The Northern Aluminium Company, Ltd., Banbury, has reprinted in book form, under the title *The Forming of Aluminium Sheet*, a series of articles on the subject which were written by Mr. H. Hinxman and published separately. In all there are ten chapters, starting with characteristics of the metal, followed by a review of the various methods of bending and a discussion of the equipment and technique for spinning. The next operation considered is the deep drawing and pressing of the metal and then drop hammer forging is broadly discussed, while a separate chapter touches upon rubber die pressing and its problems. In chapter seven the advantages of stretch-forming are demonstrated and this is followed by notes upon hand forming operations, while blanking and piercing operations form the subject matter for the penultimate section. The last chapter touches upon several supplementary operations, such as expanding, contracting, curling, embossing, coining and stamping.



Drilling, boring and tapping machine with a rotary and traversing work-table

Horizontal Drilling, Boring and Tapping Machine with Swivel Head

A HORIZONTAL drilling, boring and tapping machine, equipped with a rotary and traversing work-table, and swivel head has recently been constructed by Kitchen and Wade, Ltd., Halifax. As can be seen from the illustration below, the machine comprises two traverse beds bolted together at right-angles with the drilling saddle column mounted on one of the beds and a work-table base on the other.

The drilling column has 4ft of traverse on four enclosed ball bearing rollers on the slide-ways, to which it can be firmly secured when set. The swivel saddle encloses all driving mechanism, and it can be set up to an angle of 20 deg. above or below the horizontal centre line. This swivel saddle is firmly secured to the slide, which has a long bearing surface on the column, and locking motions are provided for the saddle and column movements. The drilling head has a vertical traverse of 4ft on the column. The splined spindle has a minimum diameter of 2in and at the nose it is bored No. 5 Morse taper. It is supported throughout its 18in traverse by a large diameter steel sleeve, on which the feed rack is cut. Means of both fine and rapid hand adjustments are provided to the spindle, the former by the small hand-wheel at the side and the latter by the cross handles. Once the desired spindle position has been reached a push on the cross handles engages the power feed. The cross handles can also be used for sensitive lever feed when drilling small diameter holes.

The 5 h.p. driving motor is built into the saddle and there are three rates of automatic spindle feed, ranging from eighty to 120 cuts per inch, and six spindle speeds from 500 to 30 r.p.m. Rapid power traverses are provided to the saddle vertical and column horizontal movements, and hand-wheels are fitted for fine adjustments to these motions.

The tee-slotted work-table is 5ft square and has a power traverse of 4ft towards and away from the spindle. A jacking motion facilitates rotation of the table, which can be quickly locked by plunger, in any of the four 90 deg. positions. The table is also graduated 360 deg. and may be set at any radial position.

Light Alloy Unloading Ramp

WHEN bulk materials are dumped from tippers, the utilisation of floor space depends principally on the height of the piles, and this can be increased simply and cheaply by tipping from a raised platform. A ramp for this purpose has been acquired by Cornwall Mills, Ltd., Par, Cornwall, and is notable for the portability conferred by the light alloy construction. This company stocks large quantities of quartz, and the trestle, standing on a concrete floor, allows 12-ton tipping trucks to unload from a height of 4ft. The ramp is built in three parts, a trestle and two tracks : the tracks peg into holes in the steel top member of the trestle and the spacing can be varied readily. Each track consists of two aluminium channels supporting braced cross-pieces of flat strip : these are set on edge to take the weight of the vehicle. The track ends in a steel rubbing plate under the lower end and a tubular steel bearer at the top, joints between steel and aluminium being treated with zinc chromate. The trestle is also principally of light alloy, bolted up with cadmium-plated steel bolts, and since the photograph reproduced here was taken it has been panelled on the back and sides with steel to prevent mineral falling inside it. When it is required to move the ramp, the tracks are rolled away on aluminium wheels, the trestle being carried on one of them. The aluminium extrusions are to B.S.S. 1476/HE 10 WP., supplied by Northern Aluminium Company, Banbury, Oxfordshire.

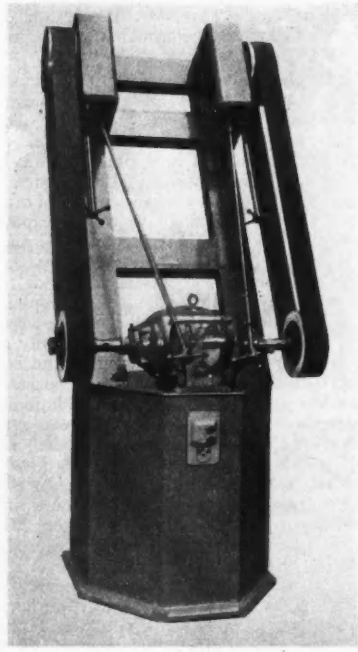
The ramp in use, showing the construction of the tracks

Abrasive Band Machine

THE double-ended upright abrasive band machine illustrated below is made by the R. J. H. Tool and Equipment Company, Ltd., Artillery Street, Heckmondwike, for a variety of grinding and polishing operations. The fabricated steel pedestal base of the machine supports the backstand idler units and carries a 4 h.p. totally enclosed motor.

The machine is designed for use with 11ft 4in by 4in wide abrasive belts. For heavy duty grinding and fettling it can be supplied with a 1500 r.p.m. motor which, with 14in diameter 4in face contact wheels, gives a band speed of 5500ft per minute. Alternatively for light duty grinding or polishing work a 3000 r.p.m. spindle speed is used with 10in by 4in contact wheels to give a band speed of 7500ft per minute. Free band strapping can also be effected above the contact wheels and the pedestal is cut away at the front to give ample working clearance round the sides of the machine.

The machine has an overall height of 7ft 9in and the spindles of both the tension and tracking handles are extended down to within easy reach of the operator to facilitate belt changing.



Upright abrasive band machine for grinding and polishing

Industrial and Labour Notes

Confederation of Shipbuilding and Engineering Unions

This week, the Confederation of Shipbuilding and Engineering Unions is holding its twentieth annual meeting at Blackpool. The meeting opened on Tuesday morning, when the delegates were addressed by the president, Mr. H. G. Brotherton.

In his address, Mr. Brotherton said that the past year had been one of full employment for almost every branch of the engineering industry. Production had risen, wages had risen—although not high enough to warrant untempered jubilation amongst the workers—and employers had enjoyed a profits boom without precedent in the history of the industry. This, Mr. Brotherton continued, had been in spite of the Government's economic policy which had been to dismantle the controls which would have helped towards the solution of long-term problems. Instead of maintaining the limitation of dividends, Mr. Brotherton added, and thus encouraging the reinvestment of capital for new equipment and expansion, there had been a "dividend spree" on a grand scale. Many companies, he claimed, had done much more than compensate their shareholders, through higher dividends and bonus share issues, for the period when they observed dividend limitation. Mr. Brotherton went on to assert that "this profits boom" had been possible because of two special factors, the first of which had been the continuous rise in industrial productivity. In the engineering industry, he remarked, output had gone up every year and was now roughly 50 per cent higher than in 1948. Clearly, Mr. Brotherton suggested, the expansion of output had added "very substantially to the profits of the employers." The second factor was that, whilst prices on the home market had continued to rise, the prices of imported materials were generally lower than three years ago. This, Mr. Brotherton contended, had increased the profit margins for many of Britain's industrialists.

Mr. Brotherton went on to say that the shipbuilding industry, hardly less than engineering, had continued to enjoy great prosperity. There had, however, been "one or two voices raised to suggest that the outlook in shipbuilding was less favourable." The basis for these fears, he thought, had been that a small number of orders for new ships which might have been expected to come to Britain had, in fact, gone to Germany. It was essential, Mr. Brotherton observed, to get the real picture into perspective and "not to be misled by isolated examples." Shipbuilding, he continued, was one of the industries in which, for quality of product, productivity and value for money, Britain could still stand comparison with any other country in the world. In the last few years the industry had revolutionised its methods of construction, and new equipment had been installed on an extensive scale. That could not have been done, Mr. Brotherton submitted, without a progressive attitude on the part of many of the firms in the industry and without the co-operation of the workers. The result had been that productivity, measured in output per worker employed, had risen in shipbuilding as much as in any other major industry. It was an inescapable conclusion, Mr. Brotherton went on, that the facts of the situation, both in engineering and shipbuilding, pointed to the submission of a new proposal to the employers, seeking improvements. Rising productivity and profits automatically generated a demand for improved conditions of employment.

Automation

In another part of his presidential address, referred to in the preceding note, Mr. Brotherton spoke about automation. He said that it was a development in production engineering which had caught the interest of the nation, though naturally it was the social problems which might arise from it that had excited the greatest concern. The employment of automatic methods in engineering, Mr. Brotherton continued, including the use of transfer machines and electronic controls of various kinds, would create an increased demand for highly skilled workers. There would be more tool makers, tool setters, draughtsmen and electrical and mechanical maintenance workers, and fewer machine operators on the production lines. Automation, Mr. Brotherton claimed, would thus reverse the tendency which had so far prevailed to replace skilled with semi-skilled and unskilled labour.

Mr. Brotherton suggested that two problems of special concern to trade unionists arose. In the first place, he said, it was essential that the extension of automatic methods should not result in widespread unemployment among men and women now employed as machine operators. The way to maintain full employment, he urged, was to ensure that the purchasing power of the "ordinary people" expanded in step with rising productivity. Similarly, the elimination of manual labour from many of the processes of production should be followed by a shortening of the hours of labour in industry, and not by mass unemployment. The second problem arising from automation, Mr. Brotherton asserted, was that of the education and training of the many highly skilled workers and technicians who would be required in increasing numbers in industry. It was the job of trade unionists, he commented, to press for the further development of the educational system and for adequate training schemes in industry.

Steel Company's Development Scheme

It has been announced by the United Steel Companies, Ltd., that Samuel Fox and Co., Ltd., is installing at its Stocksbridge works, Sheffield, a combination bar and rod mill, together with bar heat-treatment plant. This installation is being undertaken by the Brightside Foundry and Engineering Company, Ltd., and the cost of the project is put at nearly £2,500,000.

The mill will roll bars and rods in alloy, high carbon and stainless steels from 0·212in to 2½in diameter, and equivalent sizes in squares and other sections, including spring flats. In the bar heat-treatment section of the new plant, facilities will be available initially for annealing and heat-treating about 14,700 tons of material a year. The equipment to be installed includes two furnaces of 10 tons capacity and four of 4 tons capacity, the latter being served by a floor charging machine. Coke oven gas firing is to be adopted, apart from one of the 4-ton furnaces which is to be electrically heated.

It is expected that the mill will be completed in about two years. Provision is being made in the layout for the erection of an additional mill and for the extension of the bar heat-treatment plant should these be required at a future date.

Employment and Unemployment

In its latest report on the employment situation in Great Britain, the Ministry of Labour says that, at the end of June, the total working population was 23,869,000, or 1000 fewer than at the end of May. Of that total, 22,890,000 (15,156,000 men and 7,734,000 women) were in civil employment, indicating an increase of 17,000 during the month.

The Ministry's analysis of the civil employment figures for June shows that there was a net addition of 5000 to the manpower of the basic industries, making the total at the end of the month 4,008,000. The changes were seasonal, the increases occurring in transport and agriculture. Mining manpower again declined, the number of workers on colliery books at the end of June being 704,000, compared with 709,000 three months earlier. There was also a decline of 11,000 during June in the number of people employed in the manufacturing industries, the end of the month total being 9,222,000. The principal decrease occurred in textiles, although, for the first time in many months, there was a slight drop in the number of people at work in the engineering, metal goods and precision instruments group. The total labour force of the group was returned at the end of June as 2,764,000. In vehicle manufacturing, there were 1,235,000 people employed at the end of June, or 1000 more than a month earlier. The main changes during June in employment outside the basic and manufacturing industries were an addition of 3000 in building and contracting, making the total 1,460,000, and an increase of 13,000 in the number engaged in "professional, financial and miscellaneous services," making a total in that group of 4,092,000.

About unemployment, the Ministry of Labour says that the number of people—184,929—registered on July 11th as out of work, was the lowest figure recorded since the end of the war. It represented less than 1 per cent of the total number of employees and included 19,226 who were described as temporarily stopped.

Training Boiler Operators

The National Industrial Fuel Efficiency Service has prepared a pamphlet entitled "Cut Fuel Costs by Training Boiler Operators." Its purpose is to emphasise the courses of training for boiler operators which are now available at technical colleges throughout the country. In addition, the pamphlet gives some details about a new course of training which N.I.F.E.S. is to begin in October. In this course arrangements are being made to give organised practical instruction at convenient centres to "operators on the site." There will be seven whole days of practical instruction at three-weekly intervals, supplemented by material for study at home. This course has been designed particularly to overcome the difficulties of shift work, travelling, and the age groups of the men involved. Copies of the pamphlet can be obtained from Mr. S. C. Ginn, National Industrial Fuel Efficiency Service, 71, Grosvenor Street, London, W.1.

Coal Production

Coal output in recent weeks has naturally been affected by annual holidays at the pits. In the last week of July, however, prior to the August bank holiday week-end, total output, at 2,525,200 tons, was 100,000 tons higher than in the comparable week of last year. Recognised holidays caused a loss of deep-mined output estimated at 1,851,300 tons, compared with 2,083,600 tons a year ago. But last week output fell to 2,118,900 tons, compared with 2,278,400 tons in the corresponding week of 1954.

In the first thirty weeks of this year, loss of output owing to holidays was 7,863,100 tons, which was 400,000 tons or so more than in the corresponding period last year, while losses due to disputes have been estimated at 2,030,600 tons compared with 745,800 tons in the first thirty weeks of last year.

Coal imports this year, up to the end of July, had reached a total of 6,374,600 tons and distributed stocks on July 23rd amounted to 14,135,000 tons. Manpower at the collieries continues to decrease, and on July 23rd there were 702,700 wage earners on the books, compared with 706,400 a year ago. In that period the number of face workers has dropped from 290,200 to 288,600. Last week, at the request of the National Coal Board, the executive of the National Union of Mineworkers met to discuss the critical shortage of men in the coal mining industry, and to consider suggestions about taking more foreign workers. It does not appear, however, that any firm conclusions were reached. The union executive, it has been stated, decided to refer the matter to its economic committee, which has been directed to make a full inquiry into the recruitment, use and wastage of mining manpower.

High-Tensile Steel Bolts for Structural Joints

In recent years, the use of high-tensile bolts for structural joints in place of rivets has found a number of interesting applications in the United States, and the procedure involved has been standardised with the approval of the American Research Council on Riveted and Bolted Structural Joints. In our issues of March 19 and 26, 1954, we published an article which dealt with the properties of the bolts, nuts and washers employed, described a representative fastening method, and outlined a number of applications to railway bridges and other structures. The present article reviews some of the later developments in this field and describes several recent structures which were built with the aid of high-tensile steel bolts.

THE assembly of structural joints using high-strength steel bolts is a relatively new technique and results directly from the extensive research on fabricated joints which has been conducted within recent years. The use of commercial black or unfinished bolts in loose-fit holes is economical and has been common practice in America for years, but such bolts cannot be sufficiently tightened to prevent slip under working shear loads. Accordingly, their use is confined to secondary connections where slip is unimportant; elsewhere rivets are specified, to secure a better filling of the holes.

To drive tight rivets it is necessary first to bolt the parts into tight contact; high-strength bolts have been used for years for this purpose, as the force required would strip the threads of common bolts. As riveting progresses these bolts are replaced, one by one, with rivets. In the procedure to be discussed, high-strength bolts are used in all the holes. Loose-fit holes are retained for economy in assembling, but the nuts are driven home with power spanners to provide more clamping force than is possible with rivets, so that slip at working loads is not possible in view of the high friction produced between the joined members. The bolts are made of carbon steel, heat-treated for strength, and a hardened washer is placed both under the bolt-head and the nut, to permit the development of the high torque required without scoring the connected material.

To promote extensive and unified research into the subject of riveted and bolted structural joints, representatives of various groups interested in the behaviour of such joints in structures met in New York City on January 15, 1947, and organised the Research Council on Riveted and Bolted Structural Joints. The Council was formed because it was generally recognised that existing practice in the design of riveted and bolted connections had been empirically developed from experience, and that many of these practices were not supported by definite experimental data. The objective of the Council is to sponsor extensive research to promote the safer and more economical design and construction of metal structures.

In the past few years, high-strength bolts have been substituted for rivets in an increasing number of structures for commercial multi-storey buildings. To meet an increasing demand, there is now available from such firms as the Bethlehem Steel Company a range of sizes of heat-treated, high-strength carbon steel bolts specifically designed for this type of work. These bolts, together with the nuts and washers, conform to the requirements of the A.S.T.M. Specification A-325, covering "quenched and tempered steel bolts and studs with suitable nuts and washers." This specification requires a full heat-treatment, quench and temper, and in the usual structural diameters calls for mechanical properties as shown below:

Bolt size	Stress area	Threaded bolt test specimens	
		Minimum ultimate load of bolts and proof load of nuts	Minimum proof load of bolts
in	sq in	lb	lb
½	0·2256	27,000	19,180
⅝	0·3340	40,000	28,390
¾	0·4612	55,300	35,970
1	0·6051	72,600	47,200

The chemical composition specified for the bolts is such as to require the use of electric furnace or basic open-hearth steel. The nuts are required to meet a proof load equivalent to the minimum ultimate load of the bolts, as shown in the above table. The washers have to be hardened to a Rockwell "A"–68/75 value and, if carburised, they must have a minimum depth of case of 0·015in.

As a result of extensive laboratory work and field tests on structural joints fastened with high-strength bolts, the Research Council on Riveted and Bolted Structural Joints approved a "Specification for the Assembly of Structural Joints Using High-Tensile Steel Bolts." This specification was published in January, 1951, and covers the recommended practice for the fabrication of structural steel forming rigid joints using high-strength steel bolts where initial tension in the bolt body is depended upon to resist shear load through friction at the faying surfaces. Until further tests dictate otherwise, such bolts may replace rivets of the same nominal diameter. The bolt dimensions conform to the current requirements for "regular semi-finished hexagon head bolts" of the American Standards Association, except that the radius of fillet under the bolt head is not less than $^{1}/_{64}$in for sizes ⅝in and under, $^{1}/_{32}$in for sizes over ⅝in to 1in inclusive, and $^{3}/_{64}$in for sizes over 1in. The nut dimensions conform to the current requirements for "heavy hexagon semi-finished nuts" of the American Standards Association, and the washers are flat and smooth; their dimensions conform to the following table:—

Bolt size	Inside diameter	Outside diameter	Nominal thickness
in	in	in	in
½	⅝	1¼	0·109
⅝	¹³/₁₆	1½	0·134
¾	⅞	2	0·148
⅞	1	2¼	0·165
1	1⅛	2½	0·165
1⅛	1¼	2¾	0·165
1¼	1⅜	3	0·165

Where clearance makes it necessary, washers may be clipped on one side at a point not closer than seven-eighths of the bolt diameter from the centre of the washer. Where bearing faces of bolted parts are not parallel, bevelled washers may be used to compensate for any lack of parallelism. The specification requires, furthermore, that all nuts shall be tightened to give the bolt tension values listed in the following table:—

Bolt size (in)	Required bolt tension (lb)	Equivalent torque (lb-ft)
½	11,500	100
⅝	17,300	180
¾	25,600	320
⅞	32,400	470
1	42,500	710
1⅛	50,800	960
1¼	64,500	1,350

The above values of required bolt tension are equal to 90 per cent of the specified minimum elastic proof load of the bolt. The values of equivalent torque were developed on the basis of 0·0167 lb-ft per inch of bolt diameter per pound of tension, assuming non-lubricated bolts and nuts.

Condition of Contact Surfaces

A serious item of expense originally involved in the use of high-strength bolts was the need to leave bolting areas unpainted until the completion of field erection. The original American specifications required that all faying surfaces be free of paint, lacquer, oil and all other materials which would interfere with the development of friction between the parts. This requirement was established because laboratory tests had indicated the possibility of a gradual slip under long-sustained loading, due, no doubt, to a shearing action within the body of the paint film. As in the case of similar provisions usually invoked where connections are to be field-welded, it was necessary to note on the shop drawings all areas where the shop paint was to be omitted. This work in the drawing-office, together with additional work in the fabricating shop, involved in marking limits for shop painting on the steel parts, and some expense in "touching up" the shop coat in the field after erection, entailed certain additional cost. In an effort to eliminate this expense, research work has been conducted aiming at a solution to the problem, and as a result of this work a modification has now been introduced by the Research Council on Riveted and Bolted Structural Joints in its 1951 specifications. The Council, at a meeting in Chicago, declared that (except in cases of dynamic loading) the contact surfaces of joints would no longer have to be free of paint. To quote the official text: "Contact surfaces of joints in which slippage into bearing is acceptable may carry a shop coat of protective paint or lacquer. Contact surfaces of joints subjected to stress reversal, impact, or vibration, or where stress redistribution due to joint slippage would be undesirable, shall be free of paint or lacquer."

The modification was justified by the results of a continuing programme of research seeking

Fig. 1—Steelwork for car assembly works at Mahwah, New Jersey

the most efficient use of high-strength bolts. In making the change the Council considered the result of several years of study at the University of Washington on factors affecting slip in bolted joints. This work included research concerning the load at which slip may be expected to occur, and to what extent long-time loading may influence slip. It is felt that the revision in the official specifications will have an important effect in the construction of buildings, where a shop coat of paint may now be applied to bolted joints. While the Council has decided that paint on faying surfaces is a negligible factor in static loading, it found that paint should continue to be omitted from contact surfaces of joints under dynamic loading conditions such as occur in railway and highway bridges, crane runways, machinery, and other applications where stress reversal, impact, and vibration are encountered.

Two other modifications made by the Council in Chicago, while having less economic significance, are important from a design point of view. One is a change in the original specification that " where bearing faces of bolted parts are not parallel, bevelled washers shall be used to compensate for lack of parallelism." Now, however, the Council says that " flat washers may be used if the abutment surfaces adjacent to the bolt head and nut do not have a slope of more than 1 in 20 with respect to bolt axis ; provided that, in all cases of non-parallel abutment surfaces, the nut shall be torqued against a non-sloping surface." This means that it will no longer be necessary in the United States to use bevelled washers when the head of the bolt bears against the sloping flange of broad-flange beams which are made with a slope of 1 to 20. In such slopes it has been found that the steel bolt head and the flat washer exert sufficient clamping force. However, bevelled washers are still required under both head and nut when they bear against the sloping flange of the so-called American Standard beams (joists) and channels, which have a slope of 1 to 6, and a bevelled washer is still required when the nut bears against a sloping flange of other broad-flange beams.

The experimental work conducted indicated that it is very important to put sufficient tension in the bolts. The third major revision is, therefore, the recommendation to use a bolt tension about 15 per cent higher than the required minimum for calibrating the impact wrenches which are used to tighten high-strength bolts in the field. As indicated in the table on page 239 the required minimum tension was 90 per cent of the specified minimum elastic proof load of the bolt. The new bolt tension and torque values are shown in the table herewith.

Bolt size in	Recommended bolt tension for calibrating wrenches lb	Required minimum bolt tension lb	Approximate equivalent torque for required minimum bolt tension lb-ft
½	12,500	10,850	90
⅝	20,000	17,250	180
¾	29,000	25,600	320
⅞	37,000	32,400	470
1	49,000	42,500	710
1⅛	58,000	50,800	960
1¼	74,000	64,500	1,350

Structural Steelwork Applications

The advantages of using high-tensile steel bolting in structural steelwork are now generally recognised throughout the United States. One of the first to develop the theory that a high-strength bolt, with its high clamping force, would be superior to a rivet was Professor W. M. Wilson, of the University of Illinois. He drew this conclusion originally from a study of rivets as structural fasteners—long before the post-war shortage of riveters led to the demand for high-strength bolts. Later investigations at Northwestern University and elsewhere indicated the practicability of using the bolts in bridges, heavy equipment and multi-storey buildings. Once the Research Council established the original specifications in 1951, the demand for bolts spread among structural engineering contractors who were hampered by the lack of trained riveting crews in many parts of America. The American Institute of Steel Construction estimates that, beginning with a dozen buildings bolted together in 1952, high-strength bolt construction has been applied to more than 250,000 tons of structural steelwork erected across the United States with the notable exception of New York City. Manhattan's building code still limits bolted structures to a height of 125ft. In contrast an example of cities which have modernised their codes is Denver, Colorado, which recently permitted the erection of the twenty-three-storey " Mile High Center " building by the George A. Fuller Company, with the use of over 70,000 high-strength bolts. A very large number of high-tensile bolts on one scheme—more than 1,200,000—is being used to construct process buildings for the U.S. Atomic Energy Commission project in Pike County, Ohio. Another prominent use of bolts is in the current addition of a bottom lateral system to the Golden Gate Bridge, at San Francisco, California, to strengthen it against wind action. More than 200,000 high-strength bolts are being used in this work, the erector being the Judson-Pacific-Murphy Corporation.

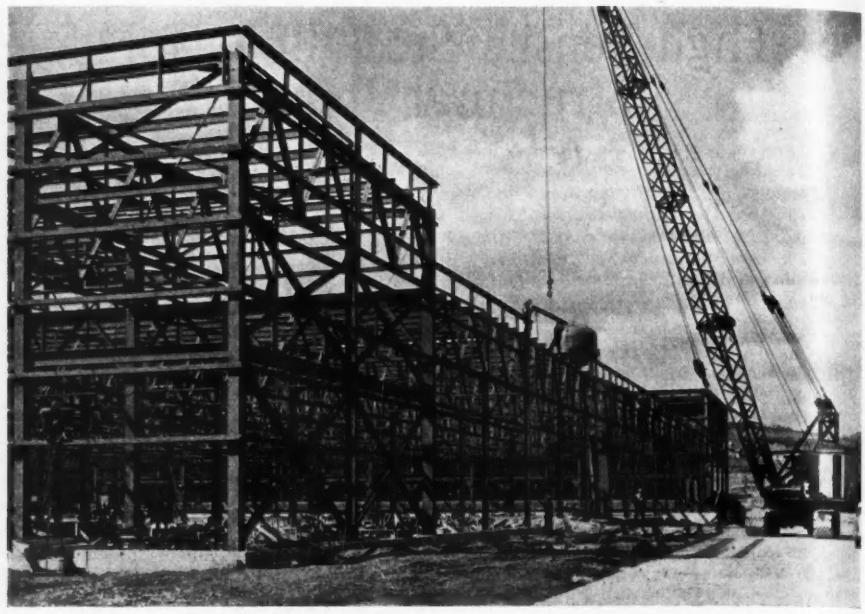


Fig. 2—Steelwork for tractor assembly works at York, Pennsylvania

The two accompanying illustrations show representative recent applications of high-tensile steel bolts in the construction of engineering works. Fig. 1 illustrates the structural steelwork at the new car assembly works of the Ford Motor Company at Mahwah, New Jersey, covering more than 1,500,000 square feet. The structural steel totalled over 9000 tons and was erected using some 127,000 high-tensile steel bolts, at a rate of up to 200 tons per day.

One of the earliest established uses of high-strength bolts was in bridges, including railway bridges, where the bolts retained their full clamping force without maintenance. This contrasted with riveted joints under dynamic loading conditions which sometimes required the re-driving of rivets every year. The experience of the railways was an early example of the considerable savings in costs made possible by using high-strength bolts in place of rivets for field connections of bridges. The railway industry has estimated that it could pare costs as much as 440,000 dollars a year by the change. The saving was expected in new construction and by avoiding the re-driving of 800,000 bridge rivets a year. Current opinion among builders is divided on the relative costs of high-strength bolts and rivets. One opinion holds, in fact, that bolt and rivet costs are equal. A recent case from Texas supports this view. In the erection of a General Motors works requiring 129,000 high-tensile bolts, bidders were asked to quote on the basis of field riveting as well as bolting. The successful low bidder submitted the same price for both methods of field fastening. But when time is a factor, there is no question that high-strength bolts are more economical because erection time is shortened. In the case of the " Mile High Center " in Denver, the Bethlehem Steel Company erected the twenty-three stories of steelwork (4600 tons) in only eighty-two working days. Another example of time-saving occurred in Cleveland. In replacing a fifty-year old foundry building of Superior Foundry, Incorporated, the general contractor was asked to streamline work to reduce production losses. With careful planning, the job was done in only thirty days—instead of the normal six months. One time-saving factor was the field-bolting of 450 tons of structural steel in seven days, or less than half the time another method of fastening would have consumed. The new foundry, built of concrete, steel and brick, covers 62,000 square feet.

Another bolting advantage is noise reduction, where this is an issue, such as in erecting an addition to an existing school or hospital. Bolts for a multi-storey building are tightened with an impact wrench, which has been found to make less than half the noise of a rivet gun. Also, the disturbance lasts less than half the time riveting requires. Among other advantages which have been related to bolts are the following:

(1) Bolts can be fastened by less skilled labour than rivets.

(2) It is more economical to use high-strength bolts as fitting-up bolts, rather than remove and replace them with rivets.

(3) Bolts can be tightened with hand spanners at field locations where power tools are not available.

(4) Since a bolt will carry greater load in shear than a rivet, the bolted joint is stronger. The Industrial Fasteners' Institute claims that two bolts will safely carry the same shear load as three rivets.

(5) As the bolts are used cold, there is no fire hazard from that source.

The general experience of the Bethlehem Steel Company concerning its use of high-strength bolts, has been summed up as follows : " We have found that the erected unit cost of a high-strength bolt is approximately the same as the cost of a rivet. In other words, the high material cost of a bolt plus its low erection cost is about equal to the low material cost of a rivet plus its high erection cost. The big advantage of high-strength bolting is the fact that the bolts can be installed quickly by an ordinary erection crew. Rivets have to be installed by skilled field riveters, who are frequently difficult to obtain. The completion of a field-riveted structure is very often delayed due to the inability of the erector to hire enough field riveters to man the job properly. Thus the saving in the use of high-strength bolts is due to a saving in overall time of completion. The time-saving feature usually produces some monetary advantage to the con-

tractor and to the owner, who can occupy a bolted building sooner than a riveted one. For these reasons, the use of high-strength bolts has grown very rapidly in the last few years, even though the direct cost of field bolting is not appreciably less than the direct cost of field riveting."

Regarding the position that fewer bolts are needed because they are stronger than rivets, the Research Council concedes that its specification allowing the substitution of one high-strength bolt for only one rivet of the same nominal diameter is very conservative. Currently there is great interest among designers as to a possible modification of this requirement in the future. Another phase of experimental research, being conducted at the University of Illinois, has to do with a proper working stress for high-strength bolts loaded externally in direct tension. Two other studies there include (*a*) static and fatigue tests of I-beam sections to gain information on bolted splices ; (*b*) bolted joints subjected to combined shear and bending. The fatigue properties of bolted joints fabricated of silicon and high-strength low alloy steels are being investigated at Northwestern University. Furthermore, two studies at Purdue University are looking into the bi-axial load effect adjacent to the bolt hole, and a determination of the most effective washer dimensions.

Calibration of Impact Tools

With regard to the tightening of bolts serving in any function, some misunderstanding arose recently over the degree of precision required. Attempts have been made to control the bolt prestress to exactly that specified in the table of the Research Council's specification on bolting

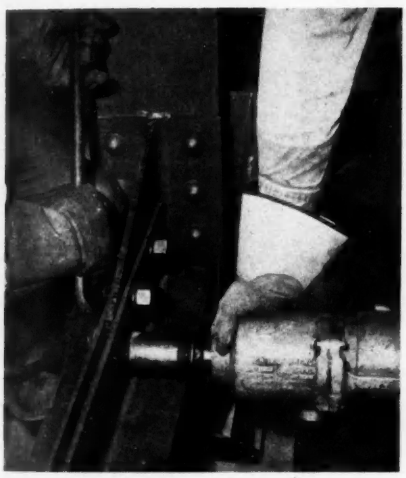


Fig. 3—Pneumatic impact wrench in operation

structural joints. The tabulated tension values—90 per cent of the specified minimum elastic proof load of the bolts—are calculated to develop nearly the maximum clamping force that can be expected of the bolts. But while no useful purpose is served when a bolt is strained beyond (rather than up to) its elastic limit, numerous field and laboratory tests have now indicated that no damage is sustained by bolts tightened well beyond their elastic proof load. They still are capable of providing a clamping force limited only by the elastic properties of the bolt. Since the minimum specified breaking strength of the bolts is not reached until a tension in excess of 150 per cent of the values given in the table has been applied, it is now felt that too meticulous attention to an upper limit of prestress is uncalled for and only serves to increase erection cost. Where pneumatic impact wrenches are used at a normal operating air pressure of 80 lb to 90 lb per square inch, about five seconds are required, after the nut first seats, before it has been turned to the desired tightness. Depending on the size of the bolts being installed, as many as six wrenches can be served by a single compressor having a capacity of 160 cubic feet per minute.

To ensure reaching the specified minimum tightness, the air pressure of the pneumatic wrenches is controlled so that the wrench will stall when the desired bolt tension is attained. It has been found that the wrench should be calibrated for the actual conditions of application at least once a day. A calibrating device used by the Bethlehem Steel Company is illustrated in Fig. 4. For each bolt size to be used, the air pressure and the approximate time of tightening required actually to stall the wrench are determined, using as many trial bolts as necessary. This procedure also serves to train the operators of the wrench. The calibrating device consists essentially of a 60-ton hydraulic pulling jack. By means of a yoke arrangement, the tension applied to the bolt by the impact wrench is read directly on the gauge mounted on the jack.

The Bethlehem Steel Company reports that its time of impacting varies from five to fifteen seconds. In practice it tightens until the wrench stalls, this point being indicated to the operator by chalk marks on the wrench socket. In a riveted joint the forging of the rivet substantially fills the rivet hole. But high-strength bolts are prestressed to such tension that friction between the connected parts alone can be relied on to transfer the stress from one member to another. One important discovery was that the use of hardened steel washers under the nut and the bolt head made possible clamping forces greatly in excess of the best that could be achieved through the shrinkage of rivets on cooling. These clamping forces are sustained without significant relaxation even after hundreds of thousands of loading cycles. In the case of bridges and other dynamically loaded structures,

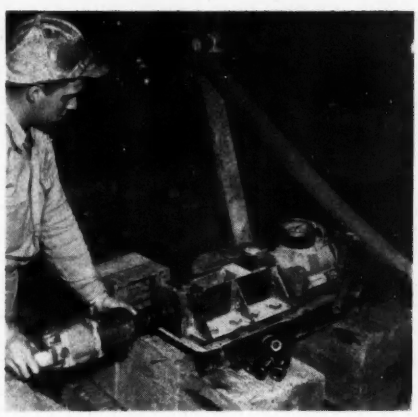
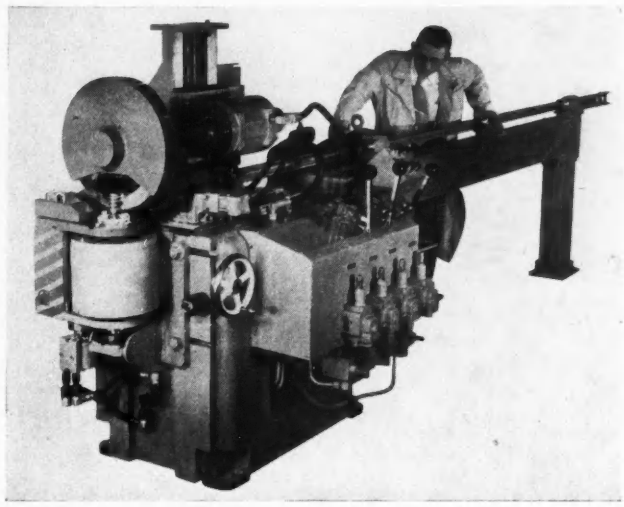


Fig. 4—Calibration of impact wrench using hydraulic jack

the demonstrated superiority of highly prestressed, high-strength bolts in providing a smoother stress path, thus materially improving the fatigue strength of the joint, is now felt to offer a distinct advantage over riveted construction. In dozens of fatigue tests, no high-strength bolt has ever failed, and neither in the laboratory nor in the field has a properly tightened bolt loosened even when subjected to extreme vibrational loads.

Automatic Tube Bending and Cut-Off Machine

A machine which produces refrigeration tubing return connectors at the rate of 3600 per hour has been designed and built by the Hautau Engineering Company, of Ferndale, Michigan, and is shown in the accompanying illustration. Operating on copper tubing, the unit bends short "U"-shapes at the tube ends and cuts them off from the remaining tube lengths. Versatility was a major object in design and the machine can produce a wide variety of bent



Automatic tube bending and cut-off machine

tubing shapes with only minor tooling changes. The hydraulic actuation may be either manually controlled or automatically cycled through the use of limit switches and solenoid valves.

Four lengths of tubing at a time are slipped over circular rod supports which are incorporated in the machine. The cycle begins when a cylinder-actuated clamp grips one end of each of the four tubes and a second cylinder feeds the tubes over a male former. A hydraulic motor then rotates a female former through 180 deg. around the male half, forming the four "U"-bends. A circular saw is then lowered on a vertical slide cutting the four bends off from the remaining lengths of tubing. The bends are removed from the male former by a spring pressure clamp which is carried on the end of a pivoting arm that is actuated by a hydraulic cylinder. The saw and the female former are then returned to their starting positions and the cycle begins again. The entire operation, which produces four complete bends, takes about four seconds. New tubes have to be loaded on to the support rods every four minutes when the machine is in operation.

Enlargement of Pineview Dam.—A contract for the enlargement of Pineview dam and other work on the Weber Basin project in Utah has been awarded to the Utah Construction Company by the United States Bureau of Reclamation. The Pineview dam and the reservoir which it forms are situated on the Ogden River, about 8 miles east of Ogden, and was constructed as a part of the Ogden River project. The contract which is now to be carried out calls for raising the Pineview dam 29ft with fills of earth and rock, reconstruction of spillways and gates, and modifying or replacing other features. The contract also calls for the relocation of over 2 miles of highway. The Weber Basin project is designed to furnish needed additional supplies of municipal, industrial and irrigation water for communities and farms on the eastern shore of Great Salt Lake, north of Salt Lake City, and other north-central parts of the State. The enlarged Pineview reservoir will continue to serve the Ogden River project and will also store additional water to serve lands under the Weber Basin project plan. The Pineview dam and reservoir was completed in 1937.

Personal and Business

Appointments

MR. F. J. CLAY has been appointed London manager of Goodwin Barsby and Co., Ltd.

MR. E. BRUCE BALL, M.I.Mech.E., has been appointed an additional director of Metal Industries, Ltd.

LONDON TRANSPORT states that Mr. J. D. C. Churchill, planning officer, has been appointed assistant secretary.

MR. H. H. MULLENS, M.I.E.E., has been appointed a non-executive director of Dorman, Long and Co., Ltd., Middlesbrough.

MR. JOHN PAISLEY, M.I.Mech.E., and SIR GILBERT DAVIS, Bt., have been appointed assistant managing directors of Eastwoods, Ltd.

MR. C. E. LUPTON has been appointed secretary and office manager of Samuel Fox and Co., Ltd., Stocksbridge Works, Sheffield.

MR. D. E. LAMBERT, M.I.E.E., has been appointed manager of the switchgear division of Brush Electrical Engineering Co., Ltd., Loughborough.

LONDON TRANSPORT announces the appointment of Mr. R. L. P. Cobb as purchasing officer, in succession to Mr. W. Hilton, who has retired.

MR. ROLLO WATERHOUSE has been appointed publicity manager of the motor-car division of Rolls-Royce, Ltd., 14-15, Conduit Street, London, W.1.

MR. P. E. HOLLOWAY has been appointed a director of the Wellman Smith Owen Engineering Corporation, Ltd., Parnell House, Wilton Road, London, S.W.1.

MR. T. H. PIKE has been appointed industrial relations officer of the Cable Makers' Association, in succession to Mr. W. H. M. Jackson who has retired.

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, Ltd., states that Mr. E. J. Vidler, general manager, and Mr. S. J. Beaney, secretary, have been appointed directors.

THE BRUSH GROUP Ltd., announces the appointment of Mr. R. H. Hainsworth as managing director of J. and H. McLaren, Ltd., Leeds, as from November 1st next.

SIEMENS BROTHERS AND CO., Ltd., announces the appointment of Dr. J. N. Aldington, M.I.E.E., as managing director. Mr. H. E. Humphries has resigned from the board.

CAPTAIN PETER WRIGHT has been appointed Commodore Commander of the fleet of the British India Steam Navigation Company, Ltd. He succeeds Captain G. A. Paterson who is retiring.

THE MINISTRY OF SUPPLY announces the appointment of Dr. E. A. Perren as chief superintendent at the Chemical Defence Experimental Establishment, Porton, in succession to Mr. S. A. Mumford.

MR. E. C. BECK, of Mowlem Paving Company, Ltd., has been elected chairman of the British Tarpaviors' Federation. Mr. S. E. Phippen, of Constable Hart and Co., Ltd., has been elected vice-chairman.

DR. NICOL GROSS, M.I.Mech.E., has been appointed deputy managing director of Quasi-Arc Company, Ltd., Bilston. At present, he is Reader in Production Engineering at the Imperial College of Science and Technology.

MR. E. H. BOWERS has been appointed a director and chief designer of Dowty Hydraulic Units, Ltd., Cheltenham. He has been chief engineer since 1953. Mr. D. E. Wiseman has been appointed a director and general manager of the company.

SPECIALLOID, Ltd., and AERO PISTON RING COMPANY, Ltd., state that Mr. T. O. Hunt has been appointed managing director in succession to Mr. R. H. Hainsworth. At present, Mr. Hunt is the technical and works director of the two companies.

MR. J. G. WISTREICH, A.M.I.Mech.E., has been appointed deputy head of the mechanical working division of the British Iron and Steel Research Association. He continues in his appointment as head of the Association's metal working laboratories at Sheffield.

THE BRITISH INTERNAL COMBUSTION ENGINE MANUFACTURERS' ASSOCIATION states that Mr. Norman McCallum, of Harland and Wolff, Ltd., has been elected chairman. Mr. Miles Beevor, managing director of Brush Group, Ltd., has been elected vice-chairman.

CROMPTON PARKINSON, Ltd., announces the appointment of Mr. P. D. Osborn as sales manager, fractional h.p. motors, in succession to Mr. R. V. Powditch. Mr. C. J. Hurd has been appointed branch manager, Home Counties, at Chelmsford, in succession to Mr. J. D. Hammond.

THE NATIONAL COAL BOARD announces the appointment of staff directors of divisional boards, as follows: Durham, Mr. H. R. Warburton; North Eastern, Mr. R. G. C. Cowe; East Midlands, Mr. P. M. D. Roberts; South Western, Mr. Watcyn V. Williams.

THE BRITISH TRANSPORT COMMISSION has announced the following appointments to British Railways' central staff: Mr. J. A. Broughall, electrical engineer (development); Mr. T. V. Nicholson, passenger officer; Mr. L. B. Marson, modernisation assistant, chief operating and motive power officer's department.

MR. BARRY KAY has been appointed Board of Trade and Ministry of Supply controller for the London and South Eastern region in succession to Mr. C. S. Toseland who is retiring. At present, Mr. Kay is Midland regional controller at Birmingham, in which appointment he is to be succeeded by Mr. A. N. Halls.

DOWDING AND MILLS, Ltd., 21–23, Rothbury Road, London, E.9, states that Mr. P. L. Hollings is now the London manager, and Mr. W. L. Henderson, London sales manager. Mr. P. A. Chambers has been appointed works superintendent and Mr. V. H. Devis, Mr. D. A. W. Clark and Mr. R. P. F. Todd are technical representatives.

HARLAND AND WOLFF, Ltd., states that Mr. Ronald Newell, M.I.Mech.E., M.I.Mar.E., engineering manager at Belfast, has been appointed to the board. Mr. F. V. Spark, director, chief accountant and secretary has retired after forty-five years in the company's service. Mr. G. H. Patton has been appointed secretary and Mr. W. T. Underwood, chief accountant.

THE LONDON MIDLAND REGION OF BRITISH RAILWAYS announces the following appointments: Mr. T. Fiske, assistant to general manager (modernisation), Euston; Mr. R. L. McIlmoyle, assistant civil engineer (modernisation), Euston; Mr. A. H. Emerson, assistant electrical engineer (modernisation), Derby; Mr. C. G. Derbyshire, assistant signal engineer (modernisation), Euston; Mr. D. S. Jewell, divisional signal engineer, Manchester; Mr. S. Vickerman, assistant to chief commercial manager (cartage), Euston; Mr. R. Tildesley, district motive power superintendent, Willesden.

Business Announcements

THE MOND NICKEL COMPANY, Ltd., states that its registered office is now at Thames House, Millbank, London, S.W.1 (telephone Victoria 3888).

THE COUNCIL OF INDUSTRIAL DESIGN states that, as from August 22nd, its address will be 28, Haymarket, London, S.W.1 (telephone, Trafalgar 8000).

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that the telephone number of its London branch sales office at 10-14, White Lion Street, N.1, has been changed to Terminus 2701.

GEORGE MACLELLAN AND CO., Ltd., Maryhill, Glasgow, has acquired a building adjacent to its premises in Shuna Street, which will provide an additional 80,000 square feet of factory space.

ARTHUR BALFOUR AND CO., Ltd., Sheffield, announces that its new Cardiff office and warehouse are situated at 55, Park Place, Cardiff (telephone, Cardiff 29715). The area manager is Mr. C. R. Hope.

THE SKEFKO BALL BEARING COMPANY, Ltd., Luton, has opened a new branch office at Waterloo buildings, London Road, Southampton (telephone Southampton 27313). Mr. L. E. Wilson is the manager of the new office.

MR. A. J. HARRIS, A.M.I.C.E., states that he has relinquished his appointment as a director of Pre-Stressed Concrete Company, Ltd., and is now established in private practice at 128, Ashley Gardens, London, S.W.1 (telephone, Victoria 6924).

GOODWIN BARSBY AND CO., Ltd., states that its London office is now at Morris House, 1–5, Jermyn Street, S.W.1 (telephone, Whitehall 0527). The firm's office in Scotland has been moved to 49, Shieldhall Road, Glasgow, S.W.1 (telephone, Govan 2888).

THE UNITED STRIP AND BAR MILLS, a wholly-owned associate of Steel, Peech and Tozer, Sheffield, has now ceased to operate under a separate name. Its activities are continued in the name of Steel, Peech and Tozer, a branch of The United Steel Companies, Ltd.

SULZER BROS. (LONDON), Ltd., 31, Bedford Square, London, W.C.1, and The Commonwealth Engineering Company, Ltd., 11, Berry Street, Granville, N.S.W., have completed negotiations for building diesel locomotives in Australia under the name "Comeng-Sulzer."

MR. H. D. ADAM, M.I.Mar.E., states that Lieutenant A. L. Giordan, R.N., ret., has joined him in his consulting practice. Their office is at 5, Whittington Avenue, London, E.C.3, (telephone Mansion House 4471).

Contracts

BRUSH BAGNALL TRACTION, Ltd., Loughborough, has received a repeat order for six 300 h.p. 0-4-0 diesel electric shunting locomotives from the Steel Company of Wales, Ltd.

DAVY AND UNITED ENGINEERING COMPANY, Ltd., Sheffield, has received an order worth about £550,000 to build a new 18in Morgan continuous skelp and strip mill for the steel works at Newcastle, New South Wales, of Broken Hill Proprietary Co., Ltd. The mill will consist of fourteen stands and will be supplied with a considerable amount of auxiliary handling and control equipment. Delivery is expected to be made early in 1957.

STANDARD TELEPHONES AND CABLES, Ltd., has been awarded a contract for the supply of twenty-three 30kW short wave transmitters to the British Post Office. The equipments will be installed at three of the British Post Office radio transmitting stations, and will be used for point-to-point multi-channel telephony and telegraphy services between the United Kingdom and all parts of the world.

THE POWER-GAS CORPORATION, Ltd., Stockton-on-Tees, has received an order from the North Thames Gas Board for a Segas catalytic oil gas installation at the Uxbridge works. The plant will consist of two Segas units, each producing 1,500,000 cubic feet of gas a day and will be complete with all necessary ancillary equipment. It is expected that the plant will be in operation by the end of 1956.

TAYLOR WOODROW, Ltd., has been awarded the contract for the construction of the second Calder Hall atomic power station. The new building, to be known as Calder Hall "B," will be alongside, and similar to, the original Calder Hall station. The contract, placed by the U.K. Atomic Energy Authority, is valued at over £2,000,000 and will take two and a half years to complete. Work will include the foundations, two 120ft high reactor buildings linked by a turbine hall and two-storey administration block, two 300ft high cooling towers and ancillary works, including roads, drainage, fencing and ducts. Taylor Woodrow, Ltd., has also begun work for the U.K. Atomic Energy Authority on another atomic contract valued at £250,000, for the preliminary site works at Chapelcross power station, Annan, Dumfriesshire (consulting engineers, Messrs. Merz and McLellan).

THE GENERAL ELECTRIC COMPANY, Ltd., has received orders from the Central Electricity Authority, for turbo-alternator sets totalling some £2,500,000. They comprise one 120MW and two 60MW sets, the alternators being direct-cooled by hydrogen at 30 lb per square inch gauge, with hollow copper conductors used for the rotor winding. Steam conditions in the turbine of the 120MW set will be 1500 lb per square inch gauge, 1000 deg. Fah. with reheat to 1000 deg Fah. The machine will have h.p., i.p., and l.p. cylinders arranged in tandem with turbine and generator rotors rigidly coupled, and a single thrust bearing. After expansion to 415 lb per square inch absolute in the h.p. cylinder, steam will pass to the reheat section of the boiler at a temperature of 700 deg. Fah., and then return to the i.p. turbine at a pressure of 375 lb per square inch absolute and temperature of 1000 deg. Fah. After expansion in the i.p. turbine, steam will pass through twin overhead pipes to the double-flow l.p. turbine. The contract includes a condenser with a cooling surface of 70,000 square feet, and a six-stage feed heating plant. For an output of 120MW the designed vacuum will be 28·9in of mercury and the final feed temperature 435 deg. Fah. The two 60MW sets will operate at steam conditions of 925 deg. Fah. and 900 lb per square inch gauge, vacuum at full output being 28·9in of mercury. The turbines will be two-casing machines similar to those previously supplied to Uskmouth, Ince and Hams Hall stations.

Miscellanea

VISIT OF SCIENTIFIC DELEGATES FROM GENEVA CONFERENCE TO HARWELL.—Britain is inviting all countries (more than sixty) taking part in the Geneva Conference on the Peaceful Uses of Atomic Energy to send representatives to visit the Atomic Energy Research Establishment at Harwell, on August 24th, when these representatives will have an opportunity to see something of British research work in civilian applications of atomic energy. Visitors will see parts of the Establishment showing different aspects of work in physics, chemistry, metallurgy, chemical engineering and nuclear reactors.

British Patent Specifications

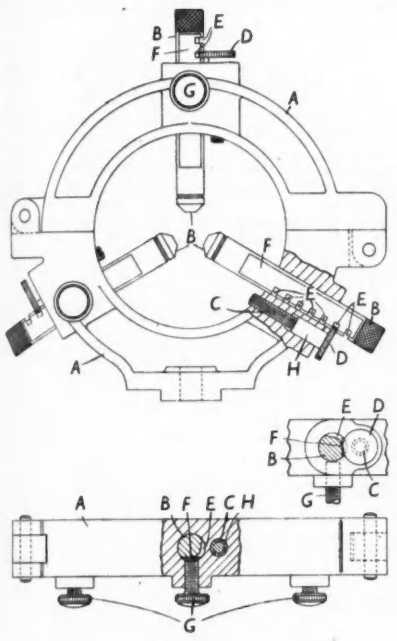
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2. 3s. each.

MACHINE TOOLS

733,315. December 13, 1952.—LATHE STEADIES, Myford Engineering Company, Ltd., and John Moore, Neville Works, Chilwell Road, Beeston, Notts.

The invention relates to improvements in lathe steadies. It is shown in the drawing that the steady comprises a bracket *A* for mounting on the lathe saddle or bed. This may be of any suitable shape and arranged to carry one, two or three plungers *B*, the inner ends of which are set to engage with the surface of the work between the lathe centres. The plungers are cylindrical and slidably mounted in bearings in the bracket. In order to move the plungers *B* longitudinally and provide a sensitive adjustment for setting their inner ends in the correct position relative to the work, a fine threaded adjusting screw *C* is



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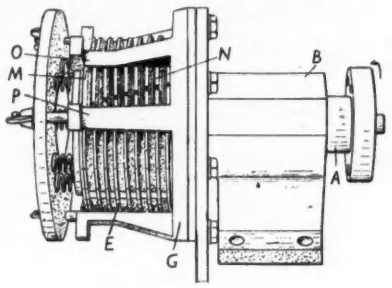
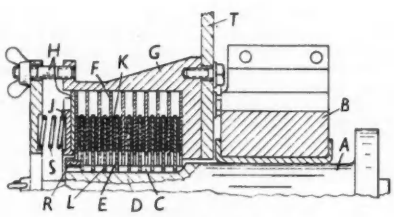
provided for each plunger. The head *D* of the screw *C* engages in a recess in the side of the plunger so that it moves with the screw as it is screwed into or out of its hole. In order that a short screw can be used for the sensitive adjustment whilst allowing for the maximum movement, the plunger is provided with a series of recesses *E* in the side, any one of which may be engaged by the head of the screw, according to the position in which it is desired to set the plunger. In order that the screw head *D* can be engaged in any one of the recesses *E* in the plunger it is formed with a flat *F* on its side, which can be brought adjacent the screw head as shown in the centre view by turning the plunger. When the flat is adjacent the screw head the plunger is free to be moved longitudinally any distance within the limits of its extreme positions. In order to hold each plunger in its normal position, a set screw *G* is provided in the bracket *A*, and the inner end of this set screw engages with the surface of the flat *F* to prevent the plunger being turned in its bearing, the set screw being withdrawn when it is desired to turn the plunger. The set screw may also be used for locking the plunger when it has been set in any desired position. The adjusting screw *C* associated with each plunger *B* is preferably formed with a cylindrical part *H* on it which fits into a housing made to receive it in the bracket so that the screw is free from shake which would otherwise occur through any slackness in the screw threads.—*July* 6, 1955.

POWER TRANSMISSION

733,249. March 17, 1953.—MULTI-DISC FRICTION CLUTCHES, COUPLINGS, BRAKES AND DYNAMOMETERS, Daimler-Benz Aktiengesellschaft, Stuttgart-Untertürkheim, Germany.

The invention relates to improvements in multi-disc friction clutches, couplings, brakes or dynamometers, and has for its particular object to ensure smooth action when reversing the direction of rotation. In the drawing, *A* is the shaft, the torque of which is received by the friction disc clutch and measured through a lever arm. *B* is a bearing in which the shaft is mounted. A longitudinal groove *C* is formed in the journal *D* of the shaft constituting a keyway for engagement by the inner discs of the clutch. *E* are the inner discs and *F* the outer discs. *G* is the outer part of the clutch, in which the outer friction discs *F* are centrally guided. *H* is a closure disc, on which a presser ring *J* is centrally mounted. On each side the friction discs are provided with annular abrasion-resisting facings *K*. The inner friction discs *E* have inwardly directed tangs *L*, which engage in the groove





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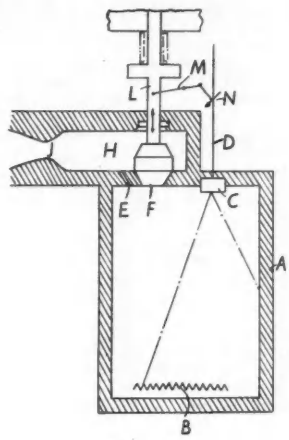
or keyway *C* in the journal. The outer friction discs have outwardly directed tangs *M*, which engage in an opening *N*, which is in effect a keyway situated between the two longitudinal bars *O* and *P* in the outer clutch part *G*. A nut *R* prevents the discs from slipping off the journal *D*. Helical springs *S* press against the presser ring *J* and are themselves placed under initial tension in accordance with the torque to be transmitted, by means of bolts provided with wing nuts, bearing against a spring abutment plate as shown. A lever *T* is mounted on the outer part *G* of the clutch and transmits the torque received to an ordinary pendulum balance. In the drawing the outer part of the clutch receives the whole of the torque from the shaft, so that the entire arrangement corresponds to the clutch part of a torque measuring device. The invention is, however, not restricted to such devices. If the outer clutch part is at the same time a part of a driven shaft or, for example, of a gear wheel, the clutch can take over the function of a safety clutch which, in the case of sudden heavy variations of torque in the driving side, protects the driving side from undesirable peak torques produced on the driven side. Such safety clutches are advantageous where large flywheel effects arise on the driven side.—*July* 6, 1955.

GAS PLANTS

733,383. February 5, 1953.—FUEL REACTION CHAMBERS, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2. (*Inventors: Douglas Francis Welch and Kenneth Barrington Randall.*)

The invention relates to a fuel reaction chamber for the decomposition of a monofuel, which contains its own oxygen for its eventual decomposition. Reaction chambers of this kind have been disclosed in the cognate co-pending Applications Nos. 13531/51 and 4616/52 (Specification No. 726,897). It is the object of the present invention to combine the function of a main and auxiliary chamber in one reaction chamber. The drawing shows a reaction chamber according to the invention in sectional elevation. Referring to the drawing, a substantially closed reaction chamber *A* is provided with a heater *B* and an inlet nozzle *C*, which atomises monofuel fed from the supply pipe *D*. The reaction chamber *A*, when operating as an auxiliary chamber, need have no initial exhaust nozzle, but if one is required then it may be placed as shown at *E*. A spring-loaded exhaust valve *F* is provided in the upper wall of the reaction chamber and this operates to open or close an orifice giving access to a duct *H* which communicates with an exhaust nozzle *J* to a utilisation device. Attached to the stem *L* of the exhaust valve is a link mechanism *M*, which is mechanically connected to a fuel supply valve *N* situated in the supply pipe *D*. The operation of the reaction chamber is as follows. The heater *B* is switched on and brought to the requisite temperature, monofuel is then supplied to the reaction chamber *A*, via inlet nozzle *C*, valve *F* is closed on its seating, decomposition of monofuel takes place in the reaction chamber which is now operating as an auxiliary chamber. The nozzle *E*, if used, permits a



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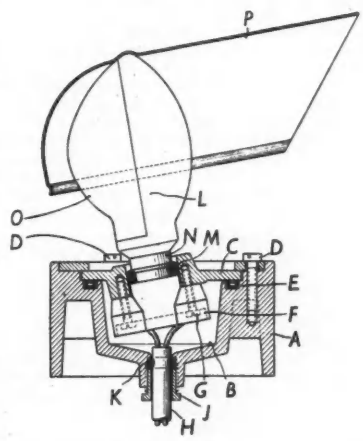
small supply of decomposed fuel to enter the duct *H*. Thus, as decomposition with an initial low rate of fuel supply occurs, pressure is built up within the auxiliary reaction chamber to open exhaust valve *F*. This increases the exhaust aperture *H*, and with the movement of the valve *F* the fuel supply valve *N* is arranged to increase the fuel supply through pipe *D* and inlet nozzle *C*, which in turn increases the pressure in the chamber *A*. The increased fuel supply will be decomposed owing to the conditions existing in the chamber and the chamber will now behave as a main reaction chamber, decomposed fuel being fed directly to the exhaust nozzle *J*.—*July* 13, 1955.

ELECTRICAL ENGINEERING

733,182. October 1, 1952.—GROUND LIGHTS, Philips Electrical Industries, Ltd., Spencer House, South Place, Finsbury, London, E.C.2.

The invention relates to ground lights which may be used on airfields. The object of the invention is *inter alia* to provide a construction which may lead to a very compact structure of ground light. In the drawing a ground light is shown in section. The ground light consists of a pot *A*, which may be made from cast iron. This pot may be sunk directly into



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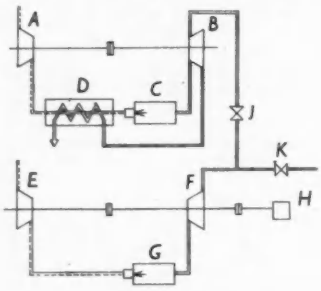
the ground, but in most cases it will first be secured in a block of cement or concrete which is sunk into the ground or under the ground, or a cover of a transformer house. The pot comprises a cavity *B*, which is closed by a disc *C*. This is forced by several screws *D* on to a rubber sealing ring *E*. The pot, together with the disc *C* and sealing ring *E*, constitute the base of the fitting. The disc *C* contains an aperture into which a lamp holder *F* is inserted from the bottom and fixed in position by means of screws *G*. A current supply cable *H* connected to the lamp holder is led in through an aperture in the base which is sealed by a gland nut *J* and a rubber ring *K*. An incandescent lamp *L* is placed in the holder *F*, a rubber ring *M* for sealing being provided between the lamp cap *N*, on the one hand, and disc *C* and lamp holder *F*, on the other hand. A silver-plated part *O*

of the bulb of the incandescent lamp is in this case shaped in such manner as to provide the desired beaming of the light. The bulb furthermore has clamped to it a hood *P*, which is manufactured from, for example, thin sheet metal and which prevents unwanted stray light. In the event of a collision the hood *P* and the lamp *L* will be destroyed, but there is no risk of moisture penetrating to the interior of the base *A*, since the lamp cap *N* will not allow the passage of water and the penetration of moisture along the lamp cap is prevented by the rubber ring *M*. Use may be made of a light source of which the envelope is not formed as an optical system. The separate optical system then to be used may be secured to the envelope of the light source in a similar manner as the hood shown.—*July* 6, 1955.

GAS TURBINES

733,538. August 21, 1953.—A STARTING ARRANGEMENT, Maschinenfabrik Oerlikon, Zürich-Oerlikon, Switzerland.

The invention aims at providing a starting arrangement which is independent of any source of electric current. In the drawing, *A* is the compressor of the main gas turbine installation ; *B*, the main gas turbine ; *C*, the combustion chamber ; *D*, a heat exchanger of the main gas turbine installation ; *E*, the compressor of the auxiliary gas turbine installation ; *F*, the auxiliary gas turbine, and *G*, its com-



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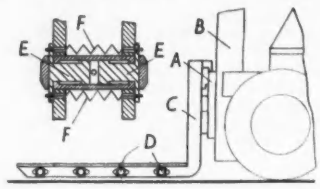
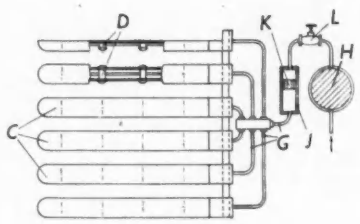
bustion chamber. Only part of the expansion takes place in the auxiliary gas turbine *F*, while another part of the pressure head is expanded in a nozzle of the main gas turbine. Mechanically connected to the auxiliary gas turbine *F* is a cartridge starter *H*. The starter first brings the auxiliary gas turbine *F* and the compressor *E* coupled to it to a speed at which independent operation is possible after ignition in the combustion chamber *G*. The speed of the auxiliary gas turbine installation is further increased by an increase of the supply of fuel to the combustion chamber *G* and part of the pressure head of the auxiliary gas turbine installation is utilised in a nozzle of the main gas turbine, which nozzle is specially designed to receive the gases of the auxiliary gas turbine installation, whereby the main gas turbine installation is also brought to the operating speed. When the starting operation has ended, the flow of gas between the auxiliary gas turbine *F* and the main gas turbine *B* is suppressed by the valve *J*, and the remaining exhaust gases of the auxiliary gas turbine can be discharged into the atmosphere through the valve *K*.—*July* 13, 1955.

CRANES AND LIFTING DEVICES

732,964. August 14, 1951.—FORK-LIFT TRUCKS, Miag Fahrzeugbau G.m.b.H., Ober-Ramstadt, Germany.

The invention concerns a fork-lift truck with a loading fork, specially adapted for handling stacks of similarly shaped articles such as bricks. As will be seen from the drawing, to the lift side *A* of a fork-lift truck *B* are attached the limbs of a fork *C* which constitute the essential part of the carrier fork. Mounted on the limbs of the fork are pressure cylinders *D*, having pistons *E* and returning springs *F*. The cylinders *D* communicate through pipes *G* with the pressure chamber or cylinder *H* of the truck. In the arrangement shown in the lower view, an intermediate cylinder *J* with a piston *K* is inserted in the pressure line *G*, and the pressure system can be turned off by some means such as a cock *L*. The carrier fork functions in the following way. When the fork *C* of the fork-lift truck *B* has been inserted into the interstices at the base of a pile of suitably stacked building stones, bricks, or the like, the lift cylinder of the vehicle is operated. As the lift slide *A* causes the fork *C* to be moved in an upward direction, pressure is applied through the pipes *G* to the cylinders *D* in the limbs of the fork. These clamping elements have rubber heads vulcanised on them. At first, the tension springs *F* prevent any protrusion of the two pistons *E* to which they are connected, but when the fork *C* takes the weight of the stack of bricks, the pressure rises automatically in the pressure chamber *H*, whereupon the clamp pistons *E* are subjected to a higher pressure, which causes them to protrude and to grip the bottom layer of bricks. The entire stack is then lifted up and can be carried away. When





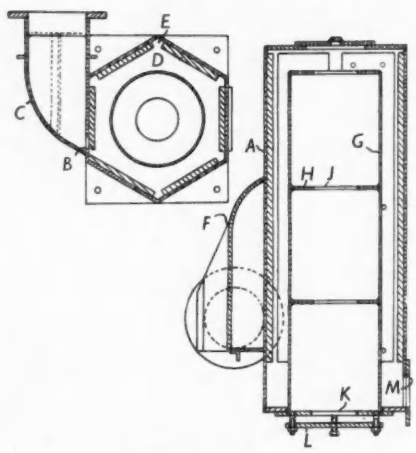
No. 732,964

the stack is set down, the pressure in the chamber *H* is reduced suddenly at the moment when the fork *C* ceases to support the bricks, whereupon the clamp pistons are withdrawn to their rest position by the springs *F*. The truck *B* can then withdraw the fork *C* from beneath the stack. Modified designs are also shown in the specification.—*July* 6, 1955.

SILENCERS AND SEPARATORS

732,936. April 30, 1953.—COMBINED SILENCER AND LIQUID OR DUST SEPARATOR, Drysdale and Co., Ltd., and John Young, both of the company's address, at Bon-Accord Works, Yoker, Glasgow.

In the drawing *A* is a vortex chamber of hexagonal form in cross section formed with an entry port *B*, and *C* a duct to direct gas to the entry port. *D* are panels of sound-absorbing material, the width of the panels being such that channels *E* are formed between the edge faces of adjacent panels. The duct is divergent as at *F* in the direction towards the port. *G* is a supplementary expansion chamber located within the vortex chamber and divided into a number of compartments by diaphragms *H*, each formed with a restricting orifice *J*. *K* is a gas discharge opening, and *L* a throttle plate movable to vary the effective area of the orifice. *M* is an opening for draining the vortex chamber or for removing residue deposited.



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In operation, gas at a pressure above atmosphere and containing dust or drops of liquid in suspension enters the vortex chamber *A* through the port *B*, and in passing through the divergent portion *F* of the duct *C* its pressure is reduced, while its velocity is increased. Since the gas enters the vortex chamber *A* in a direction tangential to a circle coaxial with the incircle of the polygon, the gas swirls around the walls of the chamber and forms a local vortex at each of the apical points of the chamber by virtue of the change of direction. These local vortices absorb and destroy the kinetic energy of the dust-laden or wet gas and reduce the noise level. At the same time, the centrifugal force being greater on the heavier particles of dust or moisture, such particles are thrown against the sides of the chamber and pass down the channels *E* to the opening *M*. The cleared or dried gas continues on its way to the supplementary expansion chamber *G*, and in passing through the restricting orifices *J* in the diaphragms *H* most of the remainder of the kinetic energy of the gas is absorbed. The final energy absorption takes place at the throttle plate *L*, masking the discharge orifice from the expansion chamber. The position of the throttle plate is adjusted to provide the maximum degree of silencing.—*June* 29, 1955.

Technical Reports

An Examination of the Flow and Pressure Losses in Blade Rows of Axial-Flow Turbines. D. G. Ainley and G. C. R. Mathieson. R+M 2891. H.M.S.O. Price 9s.—The report studies and analyses much of the available information in order to determine pressure losses and deflections and to separate the influences of such variables as blade configuration, tip clearance, Mach number, Reynolds number, &c. Particular attention is paid to secondary losses, associated with flows in the radial direction, which are shown to reach high levels in low reaction blading. Empirical charts and rules are presented, from which approximate predictions of losses and deflections can be made.

The Dielectric Properties of Acenaphthylene Styrene Copolymers (Ref. L/T286). By J. V. L. Parry. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 3s. Postage 3d.—This is one of a long series of reports from the National Physical Laboratory dealing with various aspects of the dielectric properties of materials. The copolymerisation of acenaphthylene and styrene is of interest because the resultant copolymers have higher softening points than polystyrene.

Launches and Trial Trips

BORDER SENTINEL, oil tanker ; built by Swan, Hunter and Wigham Richardson, Ltd., at the Neptune works for the Lowland Tanker Company, Ltd. ; length between perpendiculars 515ft, breadth moulded 69ft 6in, depth moulded 37ft 6in, summer draught 30ft, deadweight 16,000 tons ; service speed 13½ knots ; twenty-seven cargo oil tanks, two cargo pump rooms, four 500-ton per hour cargo oil pumps, steam deck machinery ; two 150kW diesel-driven generators, one 75kW steam-driven generator ; Swan, Hunter-Doxford oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6400 b.h.p. at 115 r.p.m., two Scotch boilers.—Launch July 19th.

LEADER, bauxite ore carrier ; built by Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., for the Pan-Ore Steamship Company, Inc. ; length overall 680ft, length between perpendiculars 650ft, breadth moulded 88ft, depth moulded 48ft, summer draught 34ft 5in ; four centre ore holds, side tanks for water ballast ; two 500kW turbo-generators, one 50kW diesel-driven generator, three 850 tons per hour ballast pumps, one 200 tons per hour pump ; one set of two cylinder articulated geared turbines, 6370 s.h.p. at 80 propeller r.p.m., steam supplied at 500 lb per square inch and 750 deg. Fah. by two Babcock and Wilcox single-pass, header pattern boilers.—Launch July 20th.

SAN FABIAN, oil tanker ; built by Smith's Dock Company, Ltd., for the Eagle Tanker Company, Ltd.; length overall 557ft, length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,000 tons on 29ft 6in draught, service speed 14¼ knots ; thirty-three cargo oil tanks, one cargo oil pump room, four 400 tons per hour turbine-driven cargo pumps, two stripping pumps, steam deck machinery ; two 550kW turbo-alternators, one 200kW diesel-driven alternator ; Hawthorn Leslie two-casing double-reduction geared turbine taking steam at 500 lb per square inch and 800 deg. Fah. from two Foster Wheeler boilers. Launch, July 21st.

SANDRINGHAM QUEEN, coaster; built by the Goole Shipbuilding and Repairing Company, Ltd., for Queenship Navigation, Ltd.; length 220ft, breadth 35ft 6in, depth 15ft 6in, deadweight 1640 tons ; British Polar diesel engine, 1120 b.h.p. at 250 r.p.m. Launch, July 21st.

D.19, dredger ; built by the Chantiers et Ateliers Augustin Normand for the French Navy ; length overall 46·30m, breadth moulded 8·50m, draught 2·17m, displacement 397 tons, speed 15 knots ; two sets of double-reduction geared gas turbines, two free-piston gas generators, 1800 h.p. Launch, July 21st.

BRITISH INTERNAL COMBUSTION ENGINE RESEARCH ASSOCIATION.—At the recent Annual General Meeting of BICERA, the Rt. Hon. the Viscount Falmouth was re-elected president. Sir Harold Roxbee Cox, Dr. S. F. Dorey, Chief Engineer Surveyor, Lloyd's Register of Shipping, and Vice-Admiral Sir Frank Mason, Engineer-in-Chief of the Fleet, were re-elected vice-presidents. Brigadier H. P. Drayson, director, Royal Engineer Equipment, Ministry of Supply, was elected a vice-president. Mr. V. H. Hopkins and Mr. A. C. Yeates were elected to the council, and Mr. J. Calderwood has been elected chairman of the council.